10 LIES ABOUT THE BRAIN
REVEALED AND EXPLAINED

THE BIG BURN
INSIDE A DEADLY WILDFIRE

& ALBERT EINSTEIN
STILL A GENIUS

POPULAR SCIENCE +

THE FUTURE OF
THE CAR
FASTER SMARTER PRINTABLE

PLUS! WE RACE A ROBOT DRIVER (GUESS WHO WINS?)

HOW ROOMBA WILL RULE YOUR HOME

THE FIRST 8K VIDEO CAMERA

THE NEW AGE BEYOND HUMAN OF BIONICS
PG. 32

The 3-D-printed Blade goes from 0-60 mph in 2.5 seconds—and you could build one in a day.

Winning Image!

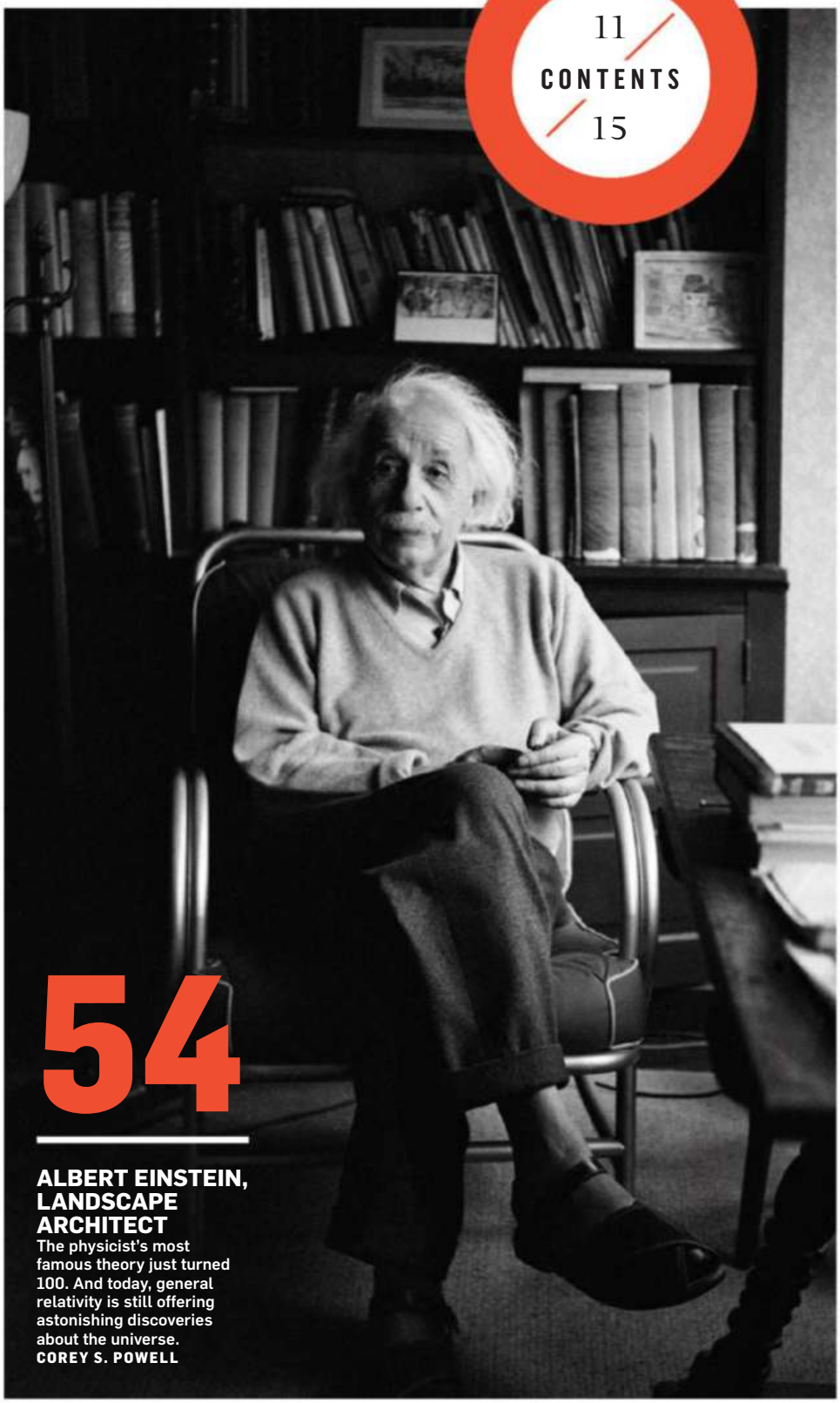
by Matt Berglund

"Wild Flower Power"
An unusually wet spring in Crested Butte, Colorado led to one of the most potent wildflower blooms in recent memory. The storms kept coming, and on this night in late June electricity fractured the sky as thunder boomed through the West Elk Mountains.

For daily updates: *facebook.com/popsci*

Volume 287 No. 5

11 / CONTENTS / 15



54

ALBERT EINSTEIN, LANDSCAPE ARCHITECT
The physicist's most famous theory just turned 100. And today, general relativity is still offering astonishing discoveries about the universe.
COREY S. POWELL

ERNST HAAS/GETTY IMAGES

Featuring

Departments

ON THE COVER
The prototype Blade supercar from Divergent Microfactories. Photo Illustration by Eric Heintz

From the Editor

In the Line of Fire

> OF ALL THE VARIABLES THAT COME TOGETHER TO FUEL A FIRE, WEATHER IS THE LEAST PREDICTABLE, AND THEREFORE THE MOST DANGEROUS.

As our November issue went to press, the American West was on track to suffer its worst fire season in recorded history. At publication, about 8.9 million acres had burned, and the worst of California's fire season still lay ahead. It will be months more before we understand the season's true cost in terms of lives lost and dollars spent.

With the deepening drought in the West, we at *Popular Science* had expected a bad fire season, and before it began, we got in touch with writer Kyle Dickman. Kyle knows wildfires. He is a former member of the Tahoe Hotshots, a wildfire-fighting crew. He also wrote *On the Burning Edge*, the definitive account of the 2013 Yarnell Hill fire in Arizona, which claimed the lives of 19 firefighters.

Kyle told us about a group of scientists who embed with wildfire-fighting crews around the country. Of all the variables that come together to fuel a fire, weather is the least predictable, and therefore the most dangerous. By making real-time micropredictions, meteorologists play a critical role in keeping firefighters safe. He wanted to deploy with one of them.

So we waited. Stories like these require a collision of events: a big burn, various approvals, and a near-magical alignment of schedules. In mid-August, we got a message from Kyle. There was a fire near Lake Chelan, Washington, and it was growing quickly. A meteorologist named Julia Ruthford was heading there immediately. He told us he'd follow in the next day or two.

For the first few days, Kyle reported the story we'd sent him after. He followed Ruthford as she and a few hundred firefighters battled a complex of blazes in eastern Washington. Then on a Thursday morning, we got a harried call. The fire had taken an unexpected turn. One valley over, winds had shifted and overtaken a crew of firefighters with tragic consequences.

At *Popular Science*, it's our position that science and technology can solve many of the planet's most pressing problems. But it's hard to hold on to that optimism in the face of the devastation brought by this season's wildfires. The issue is complex. Climate change plays a big role—no doubt. But so do forest-management techniques and urban encroachment on wilderness. Until we address these challenges, fires will continue to blight the West. And firefighters, homeowners, and state and federal budgets will continue to pay the price. Kyle uses Ruthford's experience as a window into that problem. It's a tight perspective—a scientist faced with an impossible challenge—but the story it affords is much, much bigger.

Enjoy the issue.

Cliff Ransom
Editor in Chief

Contributors

Jeremy Hsu
Tech writer Jeremy Hsu admits he's not a car guy. But the Bloodhound SSC, he says, "is guaranteed to quicken anybody's pulse." The jet-and-rocket-powered car will vie for the land-speed record of 763 mph next year. Hsu says he usually reserves his admiration for aircraft pilots, but after writing "A Fighter Jet on Wheels" (page 30), he says now he's amazed by "the pioneers who push the envelope here on Earth."

Liz Kruesi
Writer Liz Kruesi loves when art and science intersect. And so when we asked her to use origami in an engineering project for Manual ("Fold a Paper Robot," page 59), she relished the task. Her border collie mix, however, was less than thrilled with the end product. "She jumped on the bed, then crawled under it, then circled the robot," Kruesi says, "all while barking to try to scare it away."

Ryan Inzana
When illustrator Ryan Inzana did the artwork for "Brain Myths Busted" (page 48), about the bogus things we believe about our gray matter, he was shocked. "An awful lot of what I know about the brain is a pack of lies," he says. He laments that so many people—himself included—accept faulty media reporting on brain function. "I've always doubted that whole left-brain/right-brain thing," he says.

Xavier Harding
Finding the newest gadgets for "Obsessed" (page 14) each month can be a challenge: Many candidates are in their iffy Kickstarter phase. "So many are cool ideas that just don't see the light of day," says Xavier Harding, who recently joined *Popular Science* as a technology editor. A lover of gadgets himself, Harding traces his own obsession to a '90s childhood favorite: the Game Boy Color.

RANSOM: MARIUS BUGGE; COURTESY CONTRIBUTORS

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*Among interchangeable lenses for 35mm full frame image sensors (June 2015)

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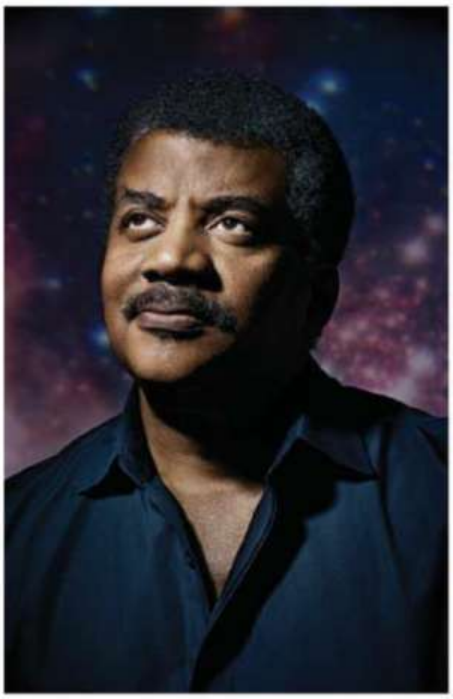

RELATIVITY OR CALCULUS?

On page 54, we honor the 100th anniversary of Albert Einstein's theory of general relativity. We now ask you the same question we put to Neil deGrasse Tyson: Albert Einstein or Isaac Newton? Tweet your answer to @PopSci with #NewtonOrEinstein. See Tyson's answer in the videos section of our Facebook page.

TWEET OUT OF CONTEXT

Can it snapchat?

@SchulerJohnny

UBER EXPENSIVE, OR CHEAP?

In "Uber Powerful" [September 2015], we outlined the car service's plan to one day launch a fleet of robotic taxis, thereby freeing people from the need to own cars. Some readers saw benefits; some did not:

MICHAEL RYAN Autonomous cars will take years to fully implement. Roads have to be redesigned so the cars can read them.

HENDRIK BERVOETS Maybe Uber is not the solution, but something like it is. I pay insurance, taxes, and maintenance for a car that stands still most of the time.

HANI MUHIEDDINE This might work in condensed cities but not large, spread-out ones like Houston, which spans 50 to 60 miles from north to south. The average person drives 25 to 30 miles each way to work. Uber would be very expensive there.

DISASTER-RELIEF SHELTER AND AIRBNB ROLLED INTO ONE

In "A Hub Away from Home" [September 2015], we described a portable living space that runs on sun, wind, and rain alone. This 14.5-foot, 1.7-ton pod can be towed or airlifted just about anywhere. Here's what our readers thought:

JOHN BAKER How do I get a job testing some of these products?

GARRY SMITH Great idea, but prohibitively expensive. Out of reach for many who could really use them.

JAMES HAGER I'd be worried about bears; is it strong enough to withstand a hungry one? If not, that limits where it can be used.

JONATHAN MYERS Just me, my mind, and some books.

HAVE A COMMENT?
Write to us at letters@popsci.com or to *Popular Science*
2 Park Ave., 9th floor
New York, NY 10016

INSIDE FACEBOOK'S AMBITIOUS QUEST FOR AI

Facebook intends to build the best artificial intelligence (AI) lab in the world—and conveniently located it just a few subway stops from *Popular Science*'s office. So how will the company integrate sophisticated AI into all of our lives? We visited the lab and spoke with its engineers to find out. Don't expect humanoid robots, but networks that can learn and solve problems, creating virtual memories and even booking flights. Read our exclusive online feature to learn more at *popsci.com/facebook-ai*.

EARLY ADOPTER

Reader Sean Hannum was enjoying a day at the beach on Lake Michigan when he turned around to see his daughter, Harper, perusing his copy of *Popular Science*. Keep on reading, Harper!

CLOCKWISE FROM LEFT: PHOTOGRAPH BY F. SCOTT SCHAFER; COURTESY NICE ARCHITECTS; COURTESY SEAN HANNUM

POPULAR SCIENCE

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REASON #32

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A Bit About Us

#CUTEOFF

Biologists on Twitter had a #Cuteoff to determine the most adorable creatures known to science. We couldn't resist contributing this nominee, called "unknown cute bee" in a book on global bee diversity featured on *popsci.com.*

HEY, SIRI

For the tech editors here at *Popular Science,* the Fall Apple Event is sort of like the Super Bowl: heavy with anticipation and subject to lots of morning-after commentary. To check out our thoughts on the big reveal—including upgrades to Apple TV and Siri, Apple Watch, iPhone 6S, and the iPad Pro with an Apple Pencil—go to *popsci.com/tags/apple-fall-2015-event.*

Q: WHAT VEHICLE WOULD YOU RACE IN A GRAND PRIX?

1 I might not win, but give me an old Mustang or Camaro, and I'd be happy.

2 As long as we're dreaming, I'd like to ride a Strandbeest (page 61) wherever it goes. I'd lose the Grand Prix but win at life.

3 A DeLorean, obviously.

4 Francois Gissy's rocket-powered bike, which hit 207 mph last year.

5 A lavender 1995 Dodge Neon sedan. If it survived my high school years, I figure it can do anything!

6 DB5 Aston Martin. Because James Bond.

7 A self-driving car, so I can just sit back and enjoy the sights.

8 Luke Skywalker's landspeeder.

Runaway Genius

In 1894, a lonely 15-year-old Albert Einstein ran away from boarding school in Munich and showed up on his parents' doorstep in Milan, much to their surprise. To learn more about Einstein's life and work, turn to page 54.

HALF-BRAINED NONSENSE

Next time anyone tells you that you're left-brained (logical) and they're right-brained (creative), you can report that they're wrong. Turn to page 48 to find more brain myths debunked.

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TOP DOWN: PHOTO BY SAM DROEGE/VIA *POPSCI.COM*; ULLSTEIN BILD/GETTY IMAGES

The Thinking Man's Guide To Choosing HOME SECURITY

"The 1980s"
Traditional Wired Home Security
Before wireless technology became available, wired security was the only option. These tend to be more expensive, because you're paying for sales guys, install guys, and a landline you don't need anymore.

"The Lite"
DIY Alarm Kits
Unlike traditional alarms, DIY kits use wireless technology so they're easy to install. But without any monitoring, they aren't adding much security.

"The Thinking Man's"
Next Generation Wireless Home Security
This new breed of home security combines the best aspects of Traditional and DIY alarms. You get 24/7 professional monitoring and instant police dispatch. It's also wireless and doesn't require hardwiring or expensive installations, so you save hundreds or more.

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Is Also Our Longest-Lasting Alkaline. It's Just One More Way We're Thinking Outside The Box.

that's positive energy.

www.*energizer*.com

A Pint-Size Companion

DANCE MACHINE

Robots continue to show up in homes, factories, and hotels. So why not your desk? The 9-inch-tall Plen desktop bot is small enough to hang out next to your coffee mug and smart enough (thanks to a microprocessor and 18 tiny motors) to perform complex movements. It can disco dance, high-five, kick a small soccer ball, lift itself up when it falls over, and even hug another robot.

You control Plen by way of a smartphone app. It comes programmed with hundreds of moves. If you get bored with Plen's preset routines, you can drive it with a joystick on the smartphone screen. Because its software is open-source, coders can invent new moves. For those who can't code, a software kit lets you manipulate Plen's arms and legs using a robot avatar on a desktop computer. Puppeteering has never been more fun. **MICHAEL NUÑEZ**

PLEN
Price $1,000
CPU 32 bit ARM7 chip
Ports USB
Battery Life 30 minutes

PHOTOGRAPH BY *Will Styer*

Obsessed

Some things are just...better

XAVIER HARDING

1 COIN 2.0

Few people enjoy storing a stack of credit cards in their wallet. Coin 2.0 trims the fat. It reprograms its magnetic strip during each purchase, allowing you to put different cards to use. Up to eight cards can be stored in the device at once. Plus it has NFC for tap-to-pay. **$100**

2 *THING EXPLAINER*

The creator of famed Web comic *xkcd* is once again venturing into the physical world with his art. Randall Munroe's newest book, *Thing Explainer*, tells how everything works—from ballpoint pens to the solar system. Required reading for the curious. **$25**

3 OAXIS INDUCTIVE SPEAKER

Moments of silence while pairing friends' phones to wireless speakers can kill a party's buzz. Oaxis hopes to make the process smoother: Just lay your device on the stereo's pad, and you're done. It supports any phone with a speaker. **$80**

4 CONNECTED CYCLE PEDALS

Replace your bike pedals with these smart ones. They pair with an app to notify you when your bike is moved and allows you to track location. Plus, these pedals are self-powered and come with their own Internet connection. **$190**

5 NEXPAQ

Build your dream phone. The Nexpaq case lets you snap in modules to your smartphone that extend battery life, improve its camera, and even add a Breathalyzer. **$65**

6 ZNAPS

This tiny charging-port attachment plugs into lightning or micro USB ports to allow the cable to attach via magnets. Non-iPhone users get an extra perk: The magnetic adapter makes micro USB connectors reversible. Finally, one fewer plug to insert wrong. **Starting at $10**

7 STANLEY VACUUM GROWLER

There are plenty of vacuum-insulated canteens, but Stanley's is one of the toughest. It keeps things steaming hot for 12 hours or ice cold for 16 hours without imparting an odd flavor or odor. **$50**

8 GOOGLE ONHUB

Wi-Fi router setup is frustrating. But Google's OnHub employs an easy-to-use app. The router even lets you assign which devices should get faster downloads, see who's connected, and troubleshoot—all from your phone. **$200**

9 SENSEL MORPH

Sensel built a pressure-sensitive trackpad—with 20,000 embedded sensors—that can morph into hundreds of input devices. Pop on piano keys if you're feeling like Beethoven, or use a paintbrush if you'd rather get your Picasso on. **$249**

10 *STAR WARS BATTLEFRONT*

What better way to prepare for Episode VII of the *Star Wars* saga this fall than to fight on behalf of the Rebel Alliance right now? *Star Wars*' videogame series' *Battlefront* is making a comeback after a 10-year hiatus, allowing you to play as classic characters and engage in online multiplayer. **$60**

CLOCKWISE FROM TOP LEFT: COURTESY NEXPAQ; COURTESY HOUGHTON MIFFLIN HARCOURT; COURTESY CONNECTED CYCLE; COURTESY ZNAPS; COURTESY QAXIS; COURTESY SENSEL; COURTESY EA; COURTESY COIN; COURTESY STANLEY; COURTESY GOOGLE


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8K Sensor Upgrade
35 megapixels

Frame Rate
100 fps @ 6K

Frame Rate on Upgrade
60 fps @ 8K capture

Monitor Output
HD-SDI and HDMI

Weight
About 3.3 lb. (brain only)

Price
Starts at $20,000

Camera brain

A CAMERA THAT SHOOTS THE STARS

What does a Hollywood legend like James Cameron have in common with a bunch of scientists on the International Space Station? They all use Red cameras to capture otherworldly landscapes.

Ever since Jim Jannard created the Red One, the company's first 4K cinema camera, in 2007, it has become a go-to shooter for serious filmmakers. Up until then, HD cameras couldn't match the resolution, dynamic range, and color of film. But the Red One could, and at a price of $17,500, it could do it for far less than the $200,000 HD units from Sony, Arri, and Panavision.

Soon after its release, the One was used to film a multiplex of blockbusters, like *Spider-Man* and *Lord of the Rings*. In 2010, it became even better with a 5K sensor—the Mysterium-X—which was sold as an upgrade. Modularity became another selling point. The company added lenses, microphones, and tactical grips. Then it rolled out the Weapon Dragon 6K camera, which captures more than nine times the pixels of standard HD, and which NASA uses on the space station; high resolution and fast frame rates capture more detail when filming experiments on the space station.

Today Jannard is betting Red can outperform itself again. The company recently introduced an 8K-sensor upgrade to the Weapon Dragon, which will enable wider angles, truer colors, and easier editing. Through a process called "downsampling," filmmakers can take an image captured at a higher resolution than monitors are even capable of displaying, and rescale it to fit lower-resolution screens—leaving cleaner, less-distorted video. Don't be surprised if your favorite science-fiction movie of next year is shot with Red. **MICHAEL NUÑEZ**

INSET PHOTO COURTESY RED CAMERA

PHOTOGRAPH BY ***Bryan Edwards***

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SHOES FOR ATHLETES WITH DISABILITIES

SLIP-ON SNEAKERS

PROBLEM

All Matthew Walzer wanted to do was tie his shoes. As a high school junior with cerebral palsy, he could dress himself but still had to ask his parents to lace up his Nikes: His hand tremors made it nearly impossible—and sort of embarrassing. So in 2012, Walzer wrote an open letter to Nike asking for help. His letter went viral and eventually made its way to designer Tobie Hatfield, who had worked with Special Olympians and Paralympians on similar challenges. It was now time to develop a prototype for Walzer.

SOLUTION

For three years, Hatfield and Walzer collaborated by phone and email. Hatfield experimented with no-lace solutions such as Velcro, zippers, and cable dials. Eventually, he decided on a wraparound zipper. The zipper on the Flyease opens near the heel and is connected with a hook-and-loop strap. Wearers can peel open the shoe with one hand, making it easier for people like Walzer (and anybody, really) to slip their foot in and out. Cords running from the heel to the top of the shoe tighten as the shoe is zipped, adding support. The sneakers fixed Walzer's shoe problem—and helped others in the process. This summer Nike outfitted two U.S. basketball teams competing in the Special Olympics with the same kicks, showing that one man's crusade can result in a win for everyone.

DAVID CASSILO

NIKE ZOOM LEBRON SOLDIER 8 FLYEASE

Price $130

PHOTOGRAPH BY ***Bryan Edwards***


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THE ALL-NEW TACOMA

Roomba's Creator and His Robot Butlers

EDITED AND CONDENSED BY
LINDSEY KRATOCHWILL

In 2002, Colin Angle sent his army of Roombas into our homes. For years they've done a great job sucking up dirt. His newest model, the 980, does a heck of a lot more. It maps your home so a future model might one day navigate it as your personal butler. Angle sat down with *Popular Science* to tell us how technology will do even more of our dirty work.

continued on next page

The Roomba 980 is smart enough to detect different floor surfaces, and it cleans each floor type differently.

PHOTOGRAPH BY *Alex Gagne*

Popular Science: How does a Roomba create a map?
Colin Angle: Because it's a vacuum, its mission in life is to get everywhere it can get to. As it moves around your home, it uses optical sensors and software to document its journey. It says, "There's nothing here, there's something here," etc. That's how it builds a map, how it understands where your rooms are. You could build a platform on that and use your cellphone to track family members in the house—like find where your husband is and have your home perform intelligent tasks to suit his location.

PS: Like what?
CA: When you map people's movements, you start extracting intent. For instance, when someone is in the living room, they probably want to watch TV, right? You can turn on the television, give a selection of their three favorite channels, and then turn it off when they leave the room.

PS: So how does that get us to the smart home of the future?
CA: As the maps get better, as we add more 3-D information about what's in your home, it's easy to imagine programming a house to stay organized, to keep the trash can where it goes, toys, magazines, and more. I imagine a robot, like a butler, with an arm that helps you clean things and fix things. It would provide security during the day, look for spills. And when you come home, it would interact with you. Or not.

In homes of the future, I imagine a robot, like a butler, with an arm that helps you clean things and fix things.

PS: What do you mean?
CA: If you want privacy, you can send the butler away. The smart home that I think of is not like other people imagine, this Starship *Enterprise* interface where the house is omniscient and omnipotent and always monitoring. That idea requires big expenses, and the concept of privacy is blurred. What I'm talking about is a distinct thing that is either with you or not with you. If it's not with you, you have privacy.

PS: Sounds like a companion bot.
CA: It can be. People already love to anthropomorphize their Roombas and name them. The Roomba on the main floor of our house is Roswell. At first our little poodle, Daphne, was very skeptical of Roswell and liked to try to chase its side brush. But quite quickly Roswell and Daphne have formed a fine relationship, and Daphne occasionally can be seen hanging out with Roswell waiting for something to happen.

ZIP THROUGH HOME REPAIRS

Having the right tool and finding it in a pinch is critical to home repair. With these three new devices—and a workbench to store them in—the molding will get hung in record time. SAL VAGLICA

1 RYOBI AIRSTRIKE P320
This air-powered, cordless 18-volt nail gun sinks fasteners up to 2 inches long. All that power without the awkwardness of an air compressor hose means there's enough run time to drive 700 nails on a single charge—a room's worth of base and crown molding. **$130**

2 MILWAUKEE FUEL 2704-22
The brushless motors in Milwaukee's 18-volt drills were already efficient and powerful. But the newest drill more than doubles the torque—with 1,200 inch-pounds. It's also a half-inch shorter and a half-pound lighter than the previous model. More power in a smaller package. **$300**

3 HUSKY DOUBLE RATCHETING WRENCH SET
This combination wrench employs a ratchet at both ends—an innovative step for an open-end wrench. With its 100 locking positions, its especially useful for fastening or loosening bolts in tight spaces—like under a sink, where you might otherwise bust your knuckle. **$40**

4 HUSKY MOBILE WORKBENCH
This beefy 21-gauge workbench stores up to 1,000 pounds of tools. While the casters that help usher it around are nice, it's the wide drawers, steel construction, and integrated pegboard that really seal the deal. Keeping tools at eye level just became really easy. **$288**

PROP STYLING BY JILL EDWARDS FOR HALLEY RESOURCES

PHOTOGRAPH BY *Jonathan Kambouris*

Introducing ***The new and revolutionary*** **Jacuzzi® Hydrotherapy Shower.**

AGING = PAIN

For many, arthritis and spinal disc degeneration are the most common source of pain, along with hips, knees, shoulders and the neck. In designing the Jacuzzi Hydrotherapy Shower, we worked with expert physicians to maximize its pain relieving therapy by utilizing the correct level of water pressure to provide gentle yet effective hydrotherapy.

JACUZZI® SHOWER = RELIEF

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The Jacuzzi® Hydrotherapy Shower provides a lifetime of comfort and relief… safely and affordably.

As we age, the occasional aches and pains of everyday life become less and less occasional. Most of us are bothered by sore muscles, creaky joints and general fatigue as we go through the day- and it's made worse by everything from exertion and stress to arthritis and a number of other ailments. Sure, there are pills and creams that claim to provide comfort, but there is only one 100% natural way to feel better… hydrotherapy. Now, the world leader in hydrotherapy has invented the only shower that features Jacuzzi® Jets. It's called the Jacuzzi® Hydrotherapy Shower, and it can truly change your life.

For over 50 years, the Jacuzzi® Design Engineers have worked to bring the powerful benefits of soothing hydrotherapy into millions of homes. Now, they've created a system that can fit in the space of your existing bathtub or shower and give you a lifetime of enjoyment, comfort and pain-relief. They've thought of everything. From the high-gloss acrylic surface, slip-resistant flooring, a hand-held shower wand, a comfortable and adjustable seat, to strategically-placed grab bars and lots of storage, this shower has it all.

Why wait to experience the Jacuzzi® Hydrotherapy Shower? Call now… it's the first step in getting relief from those aches and pains.

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—Nielsen Mobile Insights, Q2 '15

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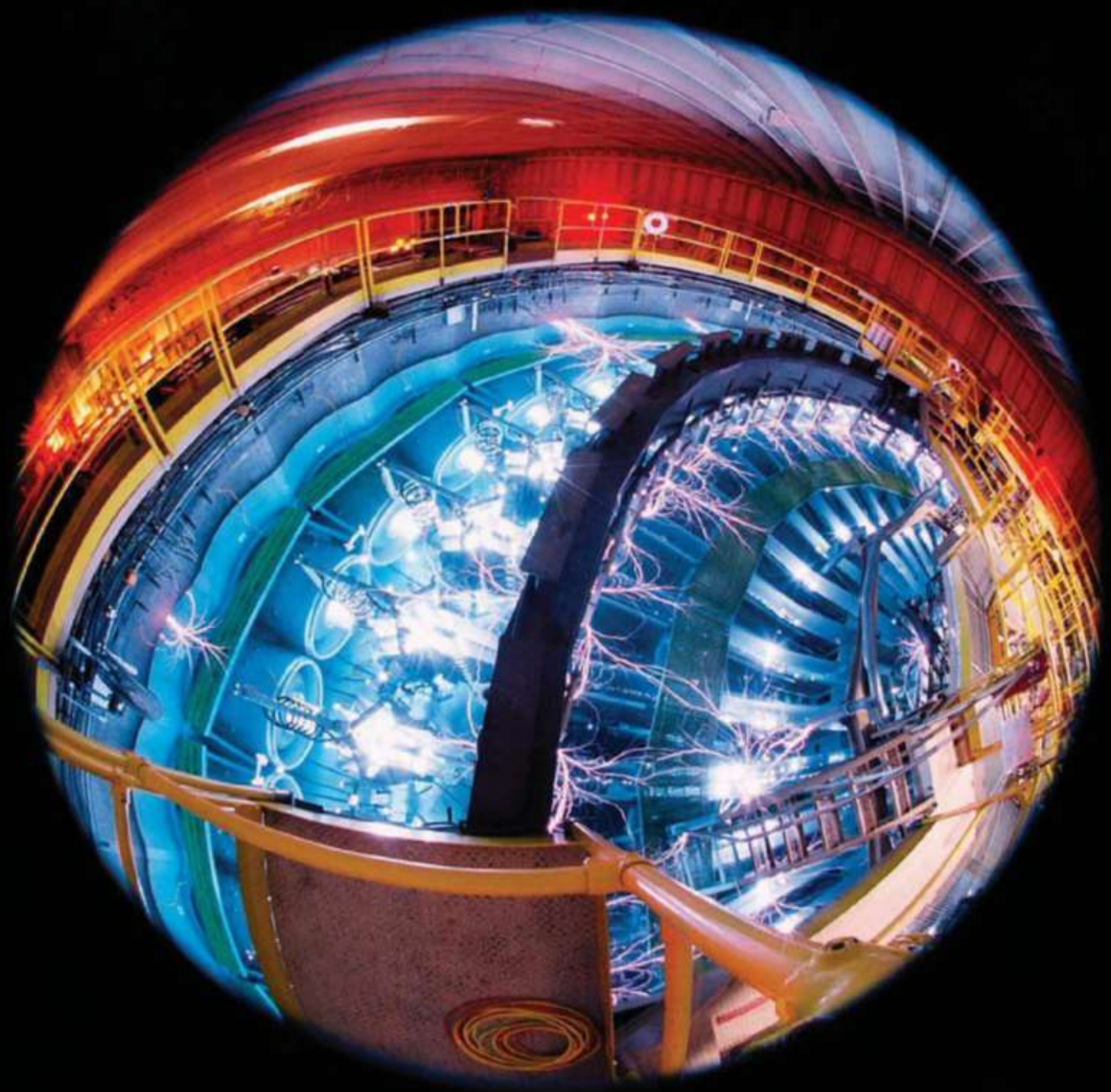
EDITED BY *Breanna Draxler & Matt Giles*



RANDY MONTOYA; COURTESY SANDIA NATIONAL LABORATORIES

For 80 years, researchers theorized that hydrogen could transform into a metal. This year, scientists at Sandia National Laboratories finally proved it. They took deuterium, an isotope of hydrogen, and applied 3 million times the atmospheric pressure using the Z machine, shown here. After 200 nanoseconds, the liquid turned reflective, indicating it had become metallic. "The moment we got our first look at the data, we were very excited," says Mike Desjarlais, the team's lead theoretical physicist. "After the first several experiments, we had begun to wonder if we would ever see it." The findings change scientists' understanding of how planets evolve. Because planets cool over time, temperature has long been used to calculate their age. But hydrogen metallization causes surface temps to rise, which could explain, for example, why Saturn is warmer than its age suggests. **MATT GILES**

20

Magnetic strength, in mega gauss, of the Z machine —20 million times greater than Earth's magnetic field

Tech Trend

Your 3-D-Printed Thanksgiving

Future holiday meals might not emerge steaming from an oven but from the heated platform of a 3-D printer. The machines have already begun to make food more sustainable, more individualized, and more interesting. "Today, food and software are very big, but very separate pieces of our lives," says Hod Lipson, a 3-D-printing pioneer at Columbia University. "There is a lot of potential in combining them." Before long, printers might be a staple in every modern kitchen, like the microwave, or the stove before it. Here are six ways they could transform your plate. **MATT GILES**

LIVING APPETIZERS

Even local produce has to be delivered. That's why food designer Chloé Rutzerveld came up with Edible Growth—printed spheres that contain yeast, spores, and seeds. In three to five days on your counter-top, they grow into living *amuse-bouches* of plants and fungi. Think Chia Pets, but tinier. And tastier.

PERSONALIZED POTATOES

Swappable "ink" cartridges make it easy to personalize printed foods. Each serving of mashed potatoes can have custom levels of vitamins and minerals, plus just the right amount of pepper. "Person A would receive this many milligrams of vitamin B12, while person B gets so many of omega 3's," says food innovator Kjeld van Bommel.

SUSTAINABLE "TURKEY"

Insects produce far less water and air pollution than livestock. They can be ground up and used to print protein with whatever taste and consistency you prefer, says Dorothée Goffin, director of the Smart Gastronomy Lab at the University of Liège in Belgium. For the bug-averse, protein-rich algae works too.

DESIGNER VEGETABLES

Cooking can turn certain foods to mush. But 3-D printers could be used as a tool to improve their texture. The result: products like vegetables that picky eaters actually want to eat. "Someday, we could print Brussels sprouts in a Mickey Mouse shape that has a crispy texture kids enjoy," van Bommel says.

"One day, 3-D printing could turn buildings and houses into mini production plants for the people who live there."

—KJELD VAN BOMMEL, SCIENTIST AT TNO, A NON-PROFIT RESEARCH ORGANIZATION

CUSTOM SIDE DISHES

Printers can cater to the food sensitivities that affect some 250 million people worldwide. Peanut allergy? Lactose intolerant? No problem. Barilla already 3-D prints pasta, so it's not a far leap to imagine printing it gluten-free. "People think 'I can buy that anyway,'" Lipson says. "But there are a thousand other foods you can't buy."

PUMPKIN PIE, REIMAGINED

Printing doesn't have to replace traditions; it can enhance them. Imagine a pie made to grandma's specifications, with a crust shaped like the Mayflower, says Liz von Hasseln of printing company 3D Systems. "We'll use the printer as a way for families to create new dishes, or twists on family recipes," she says.

One Giant Leap

GLUE WITH MORE MUSSEL

The buzz of a band saw shrieks from Jonathan Wilker's lab at Purdue University. The chemist cuts a cow femur in two and then glues it back together. A colleague does the same with metal plates—underwater. Unlike Gorilla Glue and Super Glue, which become useless when wet, Wilker's formulas are based on the super-sticking power of mussels. And they're some of the strongest glues ever made. **MEGAN MOLTENI**

INSPIRATION

Wilker drew inspiration from mollusks that cling to rocks in stormy seas. The secret to their adhesion is the cross-linking of special proteins, which he tweaked for even greater effectiveness. "In biomimicry, you don't usually beat out nature," Wilker says, "but we made some stuff that's crazy strong."

APPLICATION

Wilker thinks his glues could eliminate the need for surgical screws, plates, sutures, or staples—fixtures he says belong in carpentry or a medieval torture chamber, not modern medicine. Mussel-inspired glues could mend arteries, seal wounds, and serve in airplane and car manufacture too.

IMPACT

Today, about 99 percent of adhesives are made from petroleum or emit formaldehyde (or both). Wilker's glues provide a more sustainable, nontoxic replacement. "I don't know of anything else out there with this kind of potential," he says, "but I'm biased."

FROM TOP: ILLUSTRATION BY QUICKHONEY; FOOD COLLECTION/GETTY IMAGES

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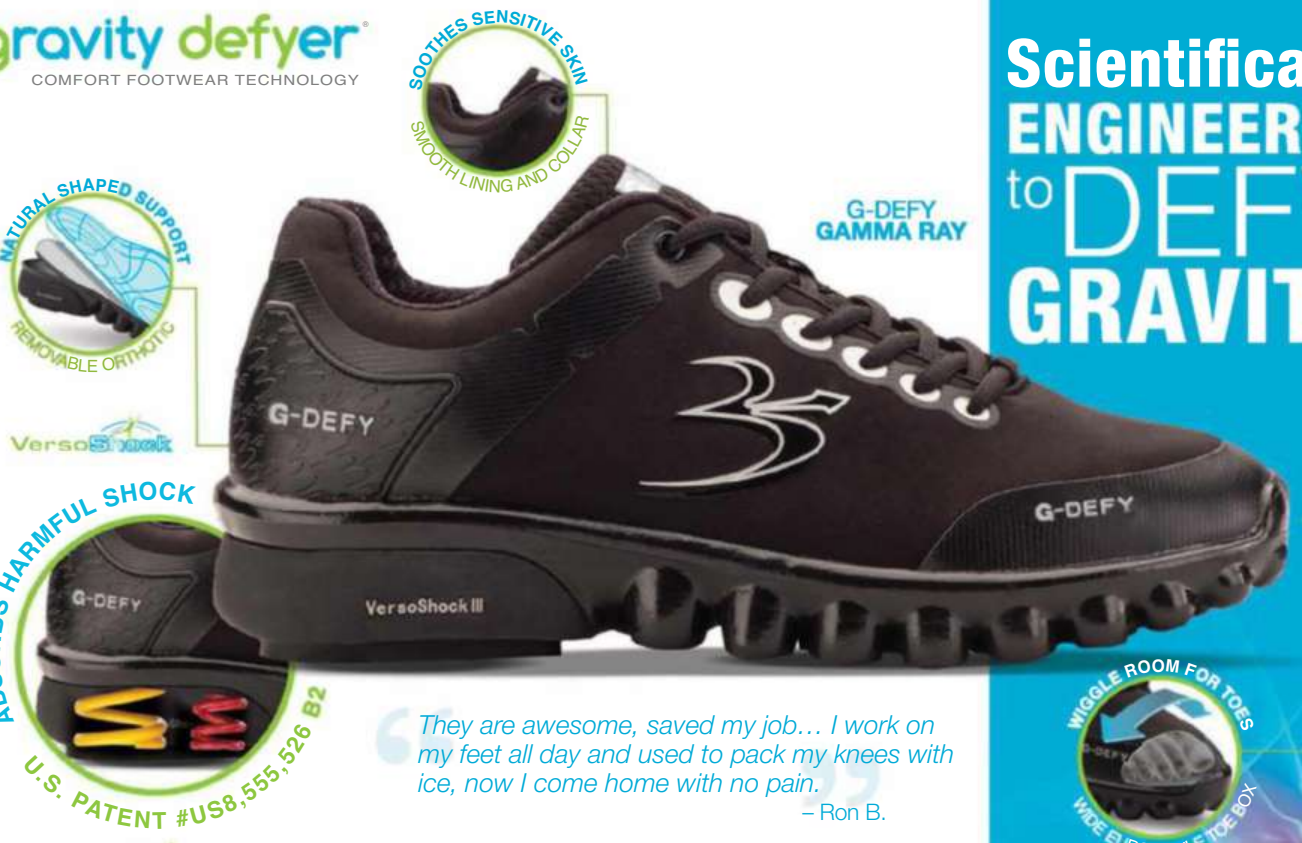

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– Ron B.

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Decoded

Electricity Tamps Down Epilepsy

By age 32, Sheri Finstad's epileptic seizures had become unbearable. She frequently fell, injured herself, and got concussions. Her doctors tried neurosurgery to better understand her condition, and a special diet and medication to treat it, to no avail. Then she enrolled in an experimental trial at the Mayo Clinic.

A surgical team implanted two stimulators, each about the size of a deck of cards, below Finstad's clavicles. They threaded wires up her neck, just beneath the skin, to four probes implanted in her brain. Doctors programmed the device to deliver a constant flow of electricity to electrodes on the probes. In deep regions of the brain, such as the thalamus and the hippocampus, this current affects the electric signals that neurons use to communicate.

"It's kind of like a pacemaker for the brain," says Zoltan Mari, director of the Deep Brain Stimulation Center at Johns Hopkins, who uses the therapy to treat dystonia and tremors associated with Parkinson's disease. But Finstad's device is even more advanced. In addition to stimulating the brain, it records her brain activity so doctors can better understand her epilepsy. In the six months since the device was implanted, Finstad has had only one major seizure.

So far, study results suggest the treatment is effective and has fewer side effects than drugs. It's now in the final stages of FDA approval. Regulators have already signed off on the therapy (with nonrecording devices) to treat epilepsy in 30 countries—including Australia, Canada, and a number of countries in the European Union.

Neuroscientists anticipate deep brain stimulation might also soon be used to treat depression, control blood pressure, and regulate metabolism. In a 2013 pilot study, obese patients who failed to lose weight after getting bariatric surgery did lose weight after stimulation of their hypothalamus, the region associated with hunger. "The brain, being a big electric board, communicates with electric signals," Mari says. "If something goes wrong with the signaling, chances are you could go in there and try to fix it at the circuit level."

Finstad must visit the doctor to transmit data from her device, but the next-gen stimulator, now in animal trials, will transfer it directly to a patient's computer. Mari predicts future devices could be even smarter, reading the neurological activity, and automatically adjusting the settings to deliver a more precise current, right when it's needed. **MURRAY CARPENTER**

Science Confirms the Obvious

DAD BOD IS REAL

If you're up on your Hollywood gossip, you've probably heard the term "dad bod"—a once-athletic build that gets extra padding after a man has kids. In June, scientists proved it's a thing. (As if we needed proof.) **LEVI SHARPE**

BODY OF DATA

Researchers at Northwestern University analyzed data on the body mass index (a weight-to-height ratio) of more than 10,000 American men over the course of 20 years. After controlling for factors such as age, race, and income, they figured out who put on the pounds.

BODY OF PROOF

Dads who live with their children showed a BMI boost of 2.6 percent. For someone 6 feet tall, that's a gain of 4.4 pounds. Dads who live under a different roof saw an increase of about 2 percent (or 3.3 pounds). The BMIs of men with no children actually dropped 1 percent—they lost 1.5 pounds.

BODY OF SNACKS

Pediatrician Craig Garfield, the study's lead author, speculates that a higher BMI is likely due to lifestyle changes linked to fatherhood. Dads often have less time for exercise and more snack food around. "And," Garfield points out, "we all know fathers who are the garbage cans to clear their family's plates."

LEFT TO RIGHT: DAN FORBES/TRUNK ARCHIVE; ILLUSTRATION BY JOREN CULL

NEW

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A FIGHTER JET ON WHEELS

BLOODHOUND SSC
Weight 17,000 pounds
Length 44 feet
Thrust 22 tons
Projected Top Speed
Mach 1.4, or 1,065 mph

When the Bloodhound SSC screams 12 miles across a South African lake bed next year, it will aim to shatter the current land-speed record of 763 mph. At that pace, it would cross nearly three soccer fields in a second. The jet-and-rocket-powered car has been in development for about a decade and packs 135,000 tons of horsepower. "We just put the car on wheels for the first time," says Mark Chapman, the Bloodhound's chief engineer. "It is going to make lots of noise, and it's definitely going to get a record." **JEREMY HSU**

1

AERODYNAMIC STABILITY
The shape of the Bloodhound's nose, body, and tail fin make it aerodynamically neutral. This ensures it doesn't go airborne. The wheels glide along the ground and act like rudders to keep the car on its lake-bed track.

2

ONE-OF-A-KIND SUSPENSION
The Bloodhound's double-wishbone suspension has a unique design: The metal A-frame that connects the front wheels is split to reduce stiffness and give the driver more steering control.

3

INDESTRUCTIBLE WINDSHIELD
The car's 1-inch-thick acrylic windshield is a tougher version of a fighter jet's canopy; it can withstand a collision with a 2-pound bird. Just to be safe, falconers will keep migratory flocks at bay, and 300 workers have spent two years clearing the track of pebbles.

ILLUSTRATION COURTESY FLOCK AND SIEMENS

4

AIR CONTROL
Shockwaves produced by the angles of the car's canopy and nose slow the airflow to 600 mph. That stabilizes the supersonic air and prevents the engine's air intake from choking with turbulence.

5

STREAMING DATA
Five hundred sensors provide real-time feedback on the Bloodhound's temperature, structural strain, and acceleration. After the first run, the driver has an hour to refuel and study the data before attempting a second—the average determines the record.

> "If we didn't have airbrake doors to create the drag, it would drive straight into Namibia."
>
> **MARK CHAPMAN,** CHIEF ENGINEER OF THE BLOODHOUND SSC

6

EXTREME DECELERATION
The car decelerates with the help of airbrake doors, which flip open like the ones on airplanes. They will slow the Bloodhound by 60 mph every second. There are also two backup parachutes.

7

RARE METAL
The wheels are made of a special-grade of aluminum alloy typically reserved for aerospace vehicles. They spin at more than 10,000 rpm without flying apart, making them the fastest wheels ever bolted onto a car. Each weighs about 200 pounds.

8

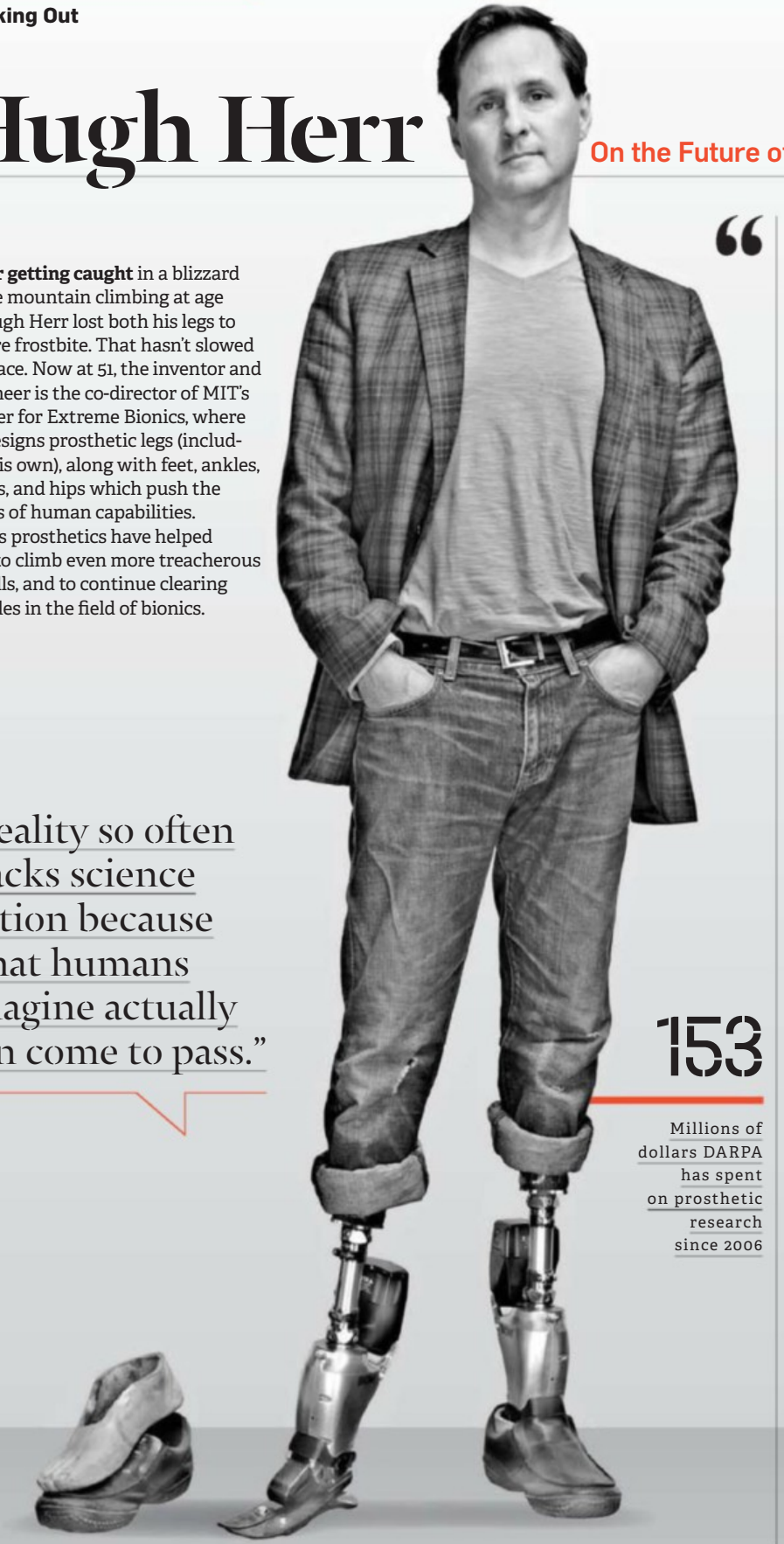
ROCKET PROPULSION
After the initial thrust of an EJ200 jet engine, which propels the car to 350 mph, three Nammo hybrid rockets kick in. "You don't get the record without all three functioning simultaneously," Chapman says. A supercharged V-8 engine supplies the rockets with high-test peroxide.

Geeking Out

Hugh Herr

On the Future of Bionics

After getting caught in a blizzard while mountain climbing at age 17, Hugh Herr lost both his legs to severe frostbite. That hasn't slowed his pace. Now at 51, the inventor and engineer is the co-director of MIT's Center for Extreme Bionics, where he designs prosthetic legs (including his own), along with feet, ankles, knees, and hips which push the limits of human capabilities. Herr's prosthetics have helped him to climb even more treacherous icefalls, and to continue clearing hurdles in the field of bionics.



"Reality so often tracks science fiction because what humans imagine actually can come to pass."

153

Millions of dollars DARPA has spent on prosthetic research since 2006

"Shortly after my amputation in 1982, I was fitted with prosthetic limbs. Their lack of technology shocked me, so I decided to design my own—ones that would enable me to return to mountain climbing. I quickly abandoned the notion that a prosthesis has to have a human shape and began optimizing function. I developed legs with adjustable heights so I could reach hand- and footholds. I had all sorts of attachments: feet to stand on rock ledges the width of a coin, and feet that would penetrate rock fissures. Within 12 months, I was climbing better than I had before my accident.

Wearing artificial limbs in the vertical world of climbing is quite comical. One time I fell, and my foot tumbled down the mountain. It would be devastating if someone's biological foot broke off. I just go to the repair shop, and in a day I have a new foot. It's upgradeable.

But in our culture, we tend to view the artificial, when it's attached to a human, as unholy. We think that our bodies are better than the devices we conceive and construct. I think that belief will disappear. Just because something is made of titanium and silicone does not mean that it's somehow less than human.

Even today, humans are very augmented: We hop in airplanes and go tremendous distances over a short period of time; we have mobile devices that improve our communications and memory. The same will happen with bionics—they will give humans transcendent capabilities.

I'm intrigued by the possibility of embedding humanity—our ideas and our creativity—into designable bodies. The artificial limbs we create can be just as beautiful and expressive as our own bodies made of innate cells.

In my lifetime, I'd like to be able to feel my synthetic legs in the way that you feel your biological legs. Hopefully I'll experience motor inventions that are superior to biological muscle tissue. To me, it's not scary; it's the natural progression of our evolution.

AS TOLD TO BREANNA DRAXLER

PHOTOGRAPH BY *Nigel Parry*

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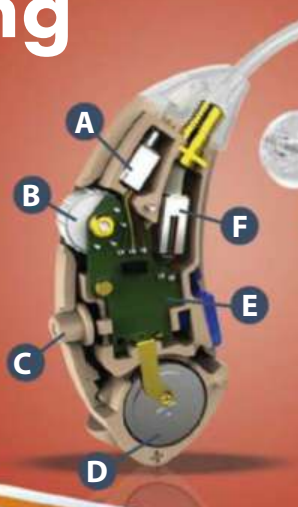

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PHOTO ILLUSTRATION BY ERIC HIENTZ

1

FRAME

To create the Blade prototype, Kevin Czinger used 69 3-D-printed aluminum connectors, called nodes, as the basis for the chassis. Those nodes act like joints that link tubes of carbon fiber. Armed with a bunch of nodes, some epoxy, and a stack of tubes, two people can assemble the Blade's chassis in 30 minutes. The result is a frame that weighs just over 100 pounds, about 10 to 20 percent the weight of a standard frame.

2

BODY

Czinger created the Blade's body from aerospace-grade carbon-fiber shearing. That allowed him to avoid the time- and energy-intense process of stamping metal body panels. Entrepreneurs, like the ones Czinger is trying to lure to his microfactory, could just as easily use Kevlar or Spandex, reducing weight even further. And, he says, body panels can be made for less than $1,000.

3

ENGINE

Like a PC-maker using third-party processors, Czinger outsourced the guts of his car, buying a custom gasoline and compressed natural gas engine from another manufacturer. The engine is small—four cylinders and 700 horsepower—but in such a light vehicle, it delivers supercar performance and is light on emissions. Czinger estimates it has less than half the carbon footprint of the Tesla Model S.

In 2010, Kevin Czinger had a revelation. As the co-founder of a small electric-car company, Coda Automotive, he had been driven by the laudable goal of creating a cleaner vehicle, one that uses less fossil fuel and emits less carbon. But as production began, he realized that "if our business scales up, with our technology, we will literally destroy the planet."

The life of a car is a dirty one. Most pollutants associated with it come not from driving it but from manufacturing it and producing its fuel, whether gas or electricity. Electric cars, particularly those with large battery systems, might generate greater environmental damage from manufacturing than their reduction in emissions offsets. To tackle the problem at its source, Czinger quit Coda and started Divergent Microfactories, which is reimagining auto manufacturing. It produced the Blade, a supercar made with 3-D-printed parts.

In essence, Divergent is a DIY-platform for small-batch carmakers. For as little as $4 million, an aspiring carmaker can get the tools and know-how to set up a microfactory. (A traditional auto factory costs around a billion dollars before the doors even open.) By using an ultralight chassis made from printed parts, would-be carmakers can reduce materials and costs. To lure clients, Czinger set up a facility in Torrance, California, to build the Blade, which runs on gasoline and compressed natural gas. At 1,400 pounds, it is more than three times lighter than a Tesla Model S and blazingly fast (zero to 60 in 2.5 seconds). More to the point, it took only seven months to go from design to car (no expensive tool-and-die shop, no delays from parts suppliers). That's a win by any measure.

BY ANDREW ROSENBLUM

MACHINE VS. MAN

TAKE HUMANS OUT OF THE EQUATION

It's a sunny morning at Sonoma Raceway, north of San Francisco—a great day for a race. My driver, Robby, pulls up to greet me. Robby is not a person. It's a car—an autonomous racecar, to be precise—and it's ready for a fight.

Outwardly, Robby is an Audi RS7 sport sedan, bright red and tarted up with black racing stripes and a giant logo. On the inside, however, it contains some of the most sophisticated autonomous-driving equipment—cameras, laser scanners, accelerometers, precision GPS receivers, microprocessors—on the planet.

As I stand there, helmet in hand, admiring the machine idling in the pit lane, Klaus Verweyen, head of Audi's piloted-driving development program, explains how the ride will go. First Robby will take me on a few hot laps around Sonoma's 2.5-mile circuit, home to many NASCAR and IndyCar races. Then I'll hop into a conventional—i.e., non-autonomous—model to try to beat that time. It's man versus machine, a John Henry-like battle for the postmodern age.

As I slide into the passenger seat, I'm greeted by a young engineer named Markus Hoffmann. He's been with the same Audi program for several years, but today his only job is to hold a kill switch that will instantly return Robby to human control if it tries anything suspicious. Besides that, he'll just enjoy the ride. I buckle up and tighten my chin strap. Then Hoffman pushes the button on the center console, and we take off down the front straight like a cannon shot. We scream through 60 mph, then 80, then 90. Turn One arrives quickly, and Robby grinds the brakes down to a perfect entry speed. The steering wheel snaps smartly to the left. At the apex, Robby throttles up and spins the wheel back in the opposite direction, carrying us smoothly out and onto the next turn.

I quickly see that Robby is very, *very* good at this. The ride is aggressive but clean, fast but not furious. It's a computer's version of a professional race lap, with precisely modulated braking yet healthy doses of tire squeal in the turns. We fly through the esses, all the while maintaining a uniformly safe distance from the walls and low curbs.

I THINK AND GUESS, WHERE ROBBY ASSESSES AND KNOWS. MY LAPS LOOK SLOPPY.

In the future, autonomous cars will need to be like Robby, able to drive fast and react to quickly changing conditions and roadways. Robby allows engineers to test autonomous systems against strains many human drivers never consider: heavy braking, load-shifting under rapid steering, sudden changes in traction when you roll over grass or gravel. Robby's driving style is also different than a human's. "Human drivers will push a car to the physical limits and then dial it back if they get in trouble," Verweyen says. "We start dialed back and then try to push harder." Because of that, Robby will always be safer, at least in theory. Hoffman hasn't had to hit that kill switch yet.

After several laps, Hoffman takes control to ease us into the pit lane, a precaution because there are people around. Then it's my turn. I get behind the wheel of a conventional RS7. I stomp the pedal to the floor. I'm not a racecar driver, but I've done my share of laps. Sonoma is tough—many turns, lots of elevation changes. Things happen quickly, and I struggle to keep up and make the right braking, steering, and throttle decisions at the right times. I realize I'm following Robby's line based on my laps with him, but just a hair more poorly, just a tad slower. I think and guess, whereas Robby assesses and *knows*. Compared with novices, my driving looks clean enough, but compared with my digital adversary, my laps are sloppy and erratic. I even hop a few of the curbs that Robby knows to avoid.

When I finally cross the finish line, my time is 2:10. Robby's is 2:02. Granted, a professional race driver familiar with the track could smoke us both; their average time is 1:55. But that's going all out. As Verweyen said, Robby is dialed back. It's just a matter of time before robot cars rule both roads and track at any speed. **BY ERIC ADAMS**

COURTESY AUDI

How Does Robby Drive?

Audi engineers program Sonoma Raceway's general specifications—its width and elevation changes—into the autonomous RS7, but it's up to the car, known as Robby (short for "robot"), to learn how to drive it in the fastest and most efficient manner. Within a few laps, Robby's sensors and cameras develop the perfect line through each turn, continually gauging the car's balance and stability in order to sort out braking, acceleration, and shift points. As the engineers throw more challenges at it—gravel, water, ice on the track, other vehicles—they'll be able to fine-tune the car's algorithms for handling such things. As a result, the self-driving sedan that will one day occupy your garage will be able to manage any threat—and maybe even give the world's greatest racecar drivers a run for their money. **E.A.**

LET IT BE LIGHT

Luxury amenities and safety enhancements have bloated our once-lightweight, easy-to-handle sports cars. Fifty years ago, for instance, the first Porsche 911 weighed in at 2,300 pounds. Today's model tips the scales at almost 3,500 pounds. This obesity epidemic—which plagues all vehicles—makes them inefficient, sluggish in turns, and in need of bigger components, such as brakes and engines, which in turn perpetuates the problem.

Alfa Romeo has trimmed the fat without losing any of the luxury or safety that we want in a sports car. At 2,487 pounds, the new 4C Spider is the first modern car with vintage weight. Instead of employing a typical steel frame, its tub-like chassis is made entirely of carbon fiber. The lightweight material allows engineers to use a smaller engine, smaller brakes to rein it in, and lighter components throughout, and its stiffness enhances handling.

The result: a high feedback car that accelerates to 60 mph in a brisk 4.1 seconds and can stop on a dime. That's supercar-level performance. Yet the 4C does not come with a supercar price tag. Alfa's greatest breakthrough might be in offering the 4C for $63,900. Cars that use comparable amounts of carbon fiber typically top $200,000. That kind of savings will make anyone feel lighter. E.A.

1
STABILITY
The 4C Spider's single-piece, carbon-fiber chassis provides structure and stiffness for improved handling. Alfa Romeo engineers hand-lay the carbon fibers to ensure they align, which in turn maximizes strength. The result is a weave that's three times stronger and seven times lighter than steel, according to the carmaker. Carbon fiber throughout the vehicle—windshield frame, trim panels, side mirrors—is mostly for appearances, but further keeps weight to a minimum.

2
HANDLING
Automobile roof structures contribute to vehicle handling, and therefore must be compensated for when cut out to create a convertible. But the inherent stiffness of the carbon-fiber frame allows engineers to make this conversion without adding extra chassis-stiffening hardware, which typically bloats a car by hundreds of pounds. The 4C Spider is only 22 pounds heavier than the coupe.

3
POWER
The turbocharged all-aluminum engine produces 237 hp, with precise fuel injection to make the most of every drop of gas. Variable-valve timing maximizes power at different RPM. The engine's placement—behind the seats—enhances balance, though it severely limits trunk space. (But this isn't a car for golf trips anyway.) The engine is mated to a rapid-response dual-clutch transmission that sends power to the wheels without interruption, even during gear shifts. Four drive modes maximize handling in different conditions.

COURTESY ALFA ROMEO

HYDROGEN NOW

FUEL CARS WITH A NEW KIND OF GAS

Like jetpacks or robot butlers, hydrogen vehicles have historically been high on promise and low on delivery. Matt McClory, an engineer at Toyota, says he can change that.

On a scalding day on the outskirts of Los Angeles, he leads me across an even more scalding parking lot to the new Toyota Mirai. The hydrogen-powered car is a first for Toyota, and it represents more than two decades of research and development. When it hits streets this fall, it will be the biggest hydrogen-vehicle launch in history (think hundreds, not dozens).

That means it carries more heft than the tiny hydrogen-vehicle launches of the past. Like Toyota's Prius nearly 20 years ago, the Mirai is more than a curiosity. It has the potential to reshape the automotive landscape.

If anyone knows the Mirai, it's McClory, who has spent eight years working on it. What makes it unique, he says, is its exceptional range: about 310 miles on a single tank. That's more than its hydrogen competition—the Honda FCX Clarity and the Hyundai Tucson Fuel Cell—and more than any electric car on the road. Even the Tesla Model S tops out around 250 miles on a charge.

Today, we'll test that efficiency. From Toyota's campus in Torrance, we'll drive west to the Pacific, then up and down the coast, racking up as many miles as time will allow, and then see how much fuel we've used. That we're driving the Mirai in California is no fluke. It's sold only here, because California is the only state with a critical mass of hydrogen filling stations. (That critical mass? Eight, though 40 more are on the way by the end of next year.)

As we set out, McClory goes over how the Mirai works. Behind me, two bottles of roughly 5 kilograms of hydrogen sit hidden beneath the back seat. The fuel-cell stack—the key to the entire operation—rests under the driver's seat. Air enters the front grill, and the oxygen combines with hydrogen in the fuel cell. The result is electricity to drive the motor, with water as the only emission. Nickel-metal hydride batteries under the hood store any electricity that's not used in the moment. (Regenerative braking also charges the batteries.) With the windows up, the only sound I hear is the subtle whine of the supercharger drawing air to the fuel cell.

> ***"FOR HYDROGEN CARS TO HAVE AN IMPACT ON SOCIETY, YOU NEED LOTS OF THEM."***

Driving through Orange County traffic is predictably stop-and-go. At the coastal highway, the road opens up. I press the pedal and the Mirai zips from zero to 60 in nine seconds—hardly a supercar but perfectly respectable. I hold fast at about 60 mph, weaving through the turns. The day has turned even hotter. Catalina Island bobs to my right.

While I drive, I keep an eye on the fuel-cell monitors in the dash. We're averaging the equivalent of 66 miles per gallon—pretty good, though it's hard to make a 1-to-1 conversion between pounds of hydrogen to gallons of gasoline. That said, we're looking a bit low, so we stop at a nearby hydrogen fueling station. Predictably, all the pumps are available, the facility is clean, and the process simple: Lock the handle to the receptacle. Five minutes later, your tanks are topped.

Fuel cells offer clear benefits. They extract more power from fuel than either electric batteries or gas engines, and that fuel can come from more places, even from landfill emissions. Also hydrogen can power big vehicles in ways batteries can't. There are only so many batteries you can cram into a bus or a semi without bumping up against the law of diminishing returns. For these reasons, McClory says, hydrogen has to be part of our alternative-fuel equation. "For fuel cells to have an impact on society and the environment, you need volume—lots of fuel-cell cars and larger vehicles," he says. I think on that. McClory said he'd convince me about the importance of hydrogen cars, and he has. The Mirai isn't flashy. It's a sedan, and an expensive one at that—about $57,500. But driving it, you get a sense that it's special—that despite the challenges of infrastructure and distribution, it might just be the next Prius. **E.A.**

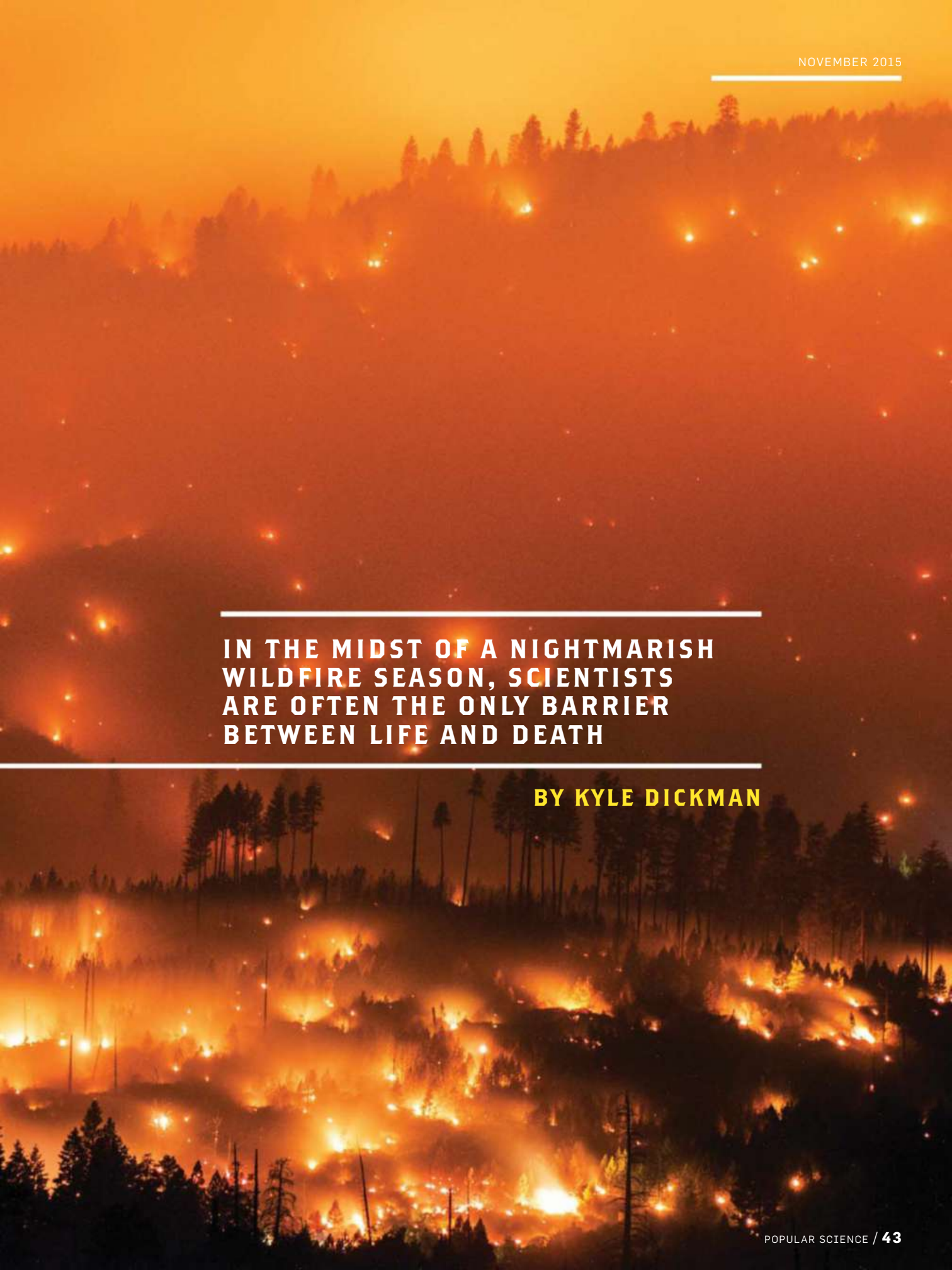
Clockwise from above: Not an engine but a power-control unit to manage the fuel cells and the system's batteries; the Mirai hits streets this fall; this plug allows the car to serve as a backup-power source for your house in case of electrical blackouts.

COURTESY TOYOTA (3)

What Will It Take?

The launch of an affordable hydrogen-powered car is a major milestone. But fuel needs to flow in order to run it. Right now, that's a problem. In some markets around the country, hydrogen gas is available via pipeline, where it's used in industrial and commercial settings. Elsewhere, it must be stored at filling stations in large pressurized tanks. So far, there are only 12 such stations in the U.S., and 10 of them are in California. Over the next five years, the state is investing $200 million and partnering with several gas providers and automakers to open 100 more. Similarly, the Department of Energy is working to expand stations nationally. Even so, hydrogen still faces a fundamental economic hurdle: Refining the gas uses a lot of energy, which makes hydrogen cars less efficient than their battery-electric and gasoline-powered peers—at least until cleaner production methods come on line. **E.A.**

ON FIRE



IN THE MIDST OF A NIGHTMARISH WILDFIRE SEASON, SCIENTISTS ARE OFTEN THE ONLY BARRIER BETWEEN LIFE AND DEATH

BY KYLE DICKMAN

AT 6 A.M.

ON AUGUST 19, JULIA RUTHFORD WALKS ONTO A MAKESHIFT STAGE IN A TENT CITY THAT'S SPRUNG UP IN CHELAN FALLS PARK, THREE HOURS EAST OF SEATTLE. A HUNDRED AND FIFTY FIREFIGHTERS, WEARING T-SHIRTS RINGED WITH DRIED SWEAT AND SMELLING OF SMOKE, WAIT TO HEAR WHAT THE DAY WILL HOLD.

Some chew tobacco. Some sip coffee from Styrofoam cups. A few hack dry coughs. The group is worn thin. For the past 22 days, many have worked 16-hour shifts fighting a group of wildfires outside Chelan, a 4,000-person town. As of that morning, 500 square miles of Washington are burning.

"It's another critical weather event," Ruthford says into a microphone. A National Weather Service meteorologist, Ruthford's responsible for a daily morning briefing, with a detailed forecast for the wildfires known as the Chelan complex. Smoke has socked in camp, and she's issued a Red Flag Warning signifying dry and unstable conditions, ideal for the rapid spread of fire.

"Expect the winds to get squirrely in here along the bend," Ruthford says. She runs a finger along the ridges by a lake on the camp's map. "Winds will start shifting from the south to the northwest after 15:00."

Ruthford's stooped shoulders and dour expression match the camp's mood. She has been forecasting weather for this fire for two weeks and knows what the blaze can do. One day, it sent 200-foot flames shooting through Douglas fir and ponderosa pine trees beneath alpine glaciers, where fires burn only every 300 to 500 years. Another day, lightning lit off a handful of new blazes around Lake Chelan, and 56,000 acres blackened in 24 hours. The strong winds she's forecasting, up to 30 miles per hour, will breathe life back into even smoldering embers.

"Be very careful out there today," Ruthford says.

After forming her forecasts in fire camp, meteorologist Julia Ruthford (right) heads to high ground to see how the predictions play out.

• • •

WEATHER DETERMINES how dangerous a fire becomes. Flames can move almost as fast as the wind, and extreme heat often creates bizarre effects. During Wisconsin's Peshtigo fire of 1871, for example, a cold front and twisting winds combined to form a fire tornado. That blaze killed 1,500 people. It burned so hot, silica in the soil evaporated. When the thunderheads rained, the mineral fell in molten form. Survivors found birds—suffocated midflight by the fire's insatiable appetite for oxygen—encased in glass.

For the Chelan complex, it's Stewart Turner's job as a fire-behavior analyst to predict how flames will spread. "The topography and fuel conditions are constants for us," Turner says. "The only thing that changes is the weather."

That's why Turner relies on incident meteorologists (IMETs). Ruthford's one of just 83 IMETs nationwide. Each holds a full-time forecasting job for local weather offices, but they're also on call for any disaster. IMETs forecasted Hurricane Katrina and Hurricane Sandy as they unfolded, as well as aftermath of the Deepwater Horizon oil spill. But most often, they're on wildfires. When working on something like the Chelan complex, Ruthford will churn out two daily forecasts, plus a long-term outlook, for an area as large as 50 square miles or as small as a stadium. Over a typical 16-hour shift, she might radio fire crews detailed changes in winds, speak at community meetings, or create forecasts for specific locations, such as a particular ridge on a fire line.

PHOTOGRAPH BY KYLE DICKMAN; OPENING SPREAD: STUART PALLEY/CORBIS

THE YEAR OF WILDFIRE

This fire season is on track to be one of the worst in recent memory. Alaska and Washington state have been particularly hard hit: 5.1 million acres have burned already in Alaska—compared to about 600,000 in a typical year—while Washington has seen its biggest single fire ever. **KATIE PEEK**

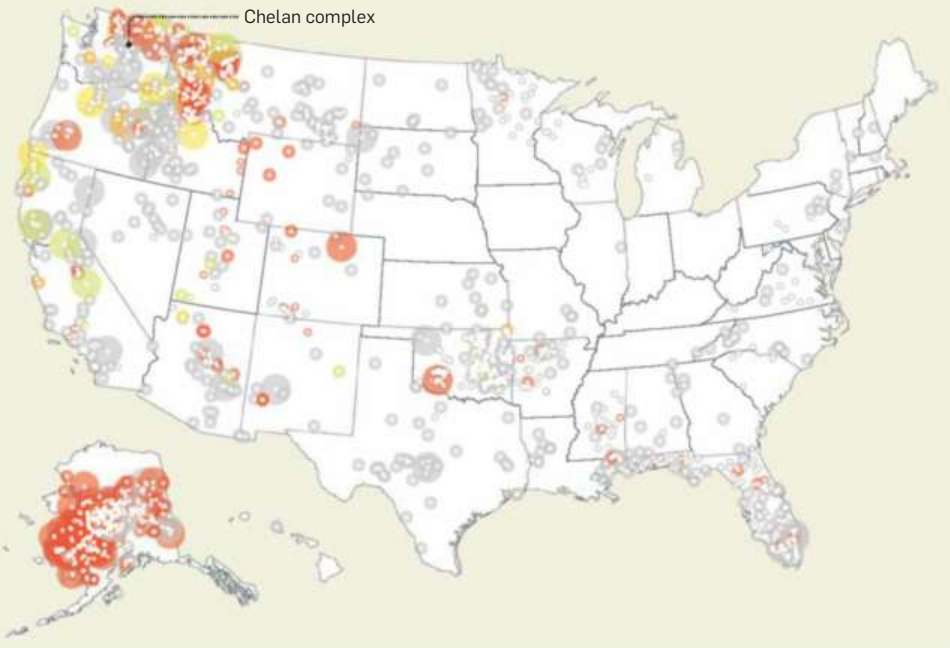
KEY

The map shows all wildfires in the United States—1,600 so far this year—as of September 21. Circles represent the approximate size of each fire in acres.

100 or fewer 101 to 10,000 10,001 or more

Color indicates how under control the fire is (percent contained).

0% 100%



2015 FIRE DATA COURTESY *GEOMAC.GOV*/U.S. GEOLOGICAL SURVEY

IMETs don't tactically plan how a fire will be fought. That's left to the firefighters, who may dismiss, overlook, or simply not receive weather forecasts, sometimes with disastrous consequences. In 1994, 14 elite firefighters died when they were surprised by a cold front that caused Colorado's South Canyon fire to detonate near Glenwood Springs. Two years ago, on Arizona's Yarnell Hill fire, sudden 50-mile-per-hour winds left 19 firefighters dead when they were trapped by a wall of fire moving toward a town. Those tragedies struck despite advanced warnings.

Today, firefighters are paying ever more attention to meteorologists. IMETs have been deployed 150 times this year and, at one point, 44 were deployed at once—a new record. But that increase has as much to do with the changing face of the American West as it does enhanced caution. Some 140 million Americans now live in places that were once wilderness and are still fire-prone. Keeping homes and people safe from the 70,000 wildfires each year demands that firefighters use all the tools available.

Money is one of them. The U.S. Forest Service, the country's largest firefighting agency, has already spent $1.4 billion sending crews, planes, and heavy machinery into the backcountry to quell flames this summer. Despite that, more than 8.9 million acres have blackened, mostly in Alaska, California, and the Pacific Northwest. By year's end, it's expected that wildfires will burn almost 10 million acres and 3,000 homes, putting 2015 on pace to be the worst fire season on record.

"THE TOPOGRAPHY AND FUEL ARE CONSTANTS FOR US," SAYS STEWART TURNER, A FIRE-BEHAVIOR ANALYST. "THE ONLY THING THAT CHANGES IS THE WEATHER."

IMETs are another important tool. Ruthford was at home in Anchorage when she got the call for the Chelan complex. Just a few days later she was lakeside at the Washington campground, scrambling to put together a forecast while flames rolled toward million-dollar Swiss-style chalets in town.

• • •

AFTER THE MORNING briefing, Ruthford returns to the grass-floored yurt where she predicts the complex interplay of wind, temperature, and barometric pressure. It's lit with floodlights, and infrared maps of the Chelan complex are pinned to the walls. There are no thermometers or barometers. Unlike firefighters, who rely on tools they can carry in their hands, Ruthford relies on weather models and her laptop.

She hunches over her computer, clicking through satellite imagery that shows water vapor rotating over the Northwest, surface temperatures along the Columbia River, and a wind map textured with moving barbs. She compares

ELAINE THOMPSON/AP/CORBIS

the way air sweeps over a landscape to the way water flows in a river, varying in speed and density based on topographical features. Pressure lines stream together and apart as she watches them move over mountains in a digital model.

Ruthford builds forecasts by stitching together a multitude of data points. Those include information gathered by the country's 123 weather-service offices, but their forecasts, accurate down to half a square mile, can't account for every nuance in terrain. So Ruthford needs local data as well. Remote Automated Weather Stations (RAWS) provide real-time updates on the fire area. She also scouts the terrain by helicopter, and every few days releases a weather balloon the size of a van to collect data above the fire.

The models are hard to manage. "All day, every day, I'm comparing what's happening now to what I thought was going to happen, and using the difference to tweak my forecasts for tomorrow," she says. Ruthford prides herself on accuracy. She's been working fires since 2003, when she was sent to a blaze 40 miles north of Chelan. During one shift, Ruthford drove out to a nearby canyon on the Thirtymile fire scar, where wind-whipped flames had killed four firefighters two years previously. Standing there convinced her she had found her calling. She had been drawn to meteorology because she wanted to find "the best spots to windsurf, ski, or kayak." But she stuck with it because of fire. "I first got into this job to play better," she says. "Now it's about protecting people." Since then, she's spent a month each year in fire camps.

In the yurt, Ruthford opens three tabs that show barometric-pressure measurements. Some days, she draws a map to visualize the pressure gradient–the greater the difference, the stronger the winds. But today, she doesn't need to. The numbers look the same. A temperature inversion has trapped a layer of hot air over the blaze, like it has for the past week. But west of the Cascades, she sees something concerning.

A band of salty marine air is blowing east off the Pacific and piling onto the 10,000-foot mountains. Ruthford's latest models tell her that around 2:00 p.m., when the air becomes deeper than the peaks are tall, it'll be forced southeast down Lake Chelan, building wind speeds up to 30 miles per hour. Nature's bellows–the reason she warned firefighters at the morning briefing. The winds will fan the flames. Powerful smoke columns will punch through the inversion, and the energy stored beneath it will erupt skyward. "It's like a lid boiled off a pot," Ruthford says. Oxygen will pour into the fire through these smoke-made holes and create its own dangerous winds. Ruthford recognizes the pattern. It's eerily similar to the storms that caused the deaths at Thirtymile.

• • •

A FEW HOURS LATER, Ruthford squeezes into the backseat of a Forest Service Chevy Tahoe. Joseph Flores, a fire-behavior analyst in training, drives. Turner rides shotgun. Ruthford often works with the smoke-distribution forecasters and fire-behavior analysts who inform tactical decisions at fire camp. They're heading to a ridge above Lake Chelan, where firefighters and bulldozers have built a fire line to keep flames out of town. Ruthford wants to see how the fire reacts to the weather she predicted in order to refine future forecasts.

The Tahoe, like almost everything in Washington state, smells of wood smoke. Occasionally, the radio pops and chatters: Somewhere on the blaze, a firefighter is worried about the threat to a cluster of about 600 homes. Just three minutes from camp, wreckage surrounds the SUV. Wisps of smoke float up in all directions.

Flores drives through a smoldering town to a ridge, where a house has been reduced to a grid of concrete slabs. The blackened remains of fruit-storage

Firefighters battling the Chelan fires, in eastern Washington, receive forecasts at the start of every day and updates throughout. They can also request forecasts for points as small as a single tree.

warehouses sit across the street. A still-smoking oak offers partial shade to the skeleton of a Town Car. As they drive by a burned-out home on the lakeshore, Ruthford says, "The last time I saw that house over there, it was standing."

"Winds aren't materializing, huh Julia?" Turner asks her from the front seat. The inversion is keeping the lid on the pot, trapping smoke over the lake like a thin fog. Over the past decade, Turner and Ruthford have worked together on a handful of fires from Alaska to Arizona, and he likes giving her a hard time.

"No, Stewart. They haven't," she says dryly. A helicopter dips a 250-gallon bucket into Lake Chelan, then drenches flames creeping toward a burned vacation home.

After an hour's drive on dirt roads so hammered by trucks that the dust covering them is fine and slippery, they stop at the fire line above the lake. Firefighters nearby ignite the forest with drip torches, metal canisters filled with diesel and gas that spread liquid flames. Setting small, strategic fires can deprive bigger blazes of fuel, stopping their advance. So far, the operation is going perfectly. The crews are hoping to blacken a mile of ridge before nightfall. Nobody seems overly concerned about the weather.

Ruthford snaps a picture of a drip torch on the ground. "I don't get to see these very often," she says. They're usually in use. Dust starts to swirl behind her in eddies. The marine air finally pushes through. The effect is instantaneous. From behind a ridge a half-mile away, there's a *whoosh* as pines ignite. Black smoke boils upward. Flames run toward different fire lines, which hold. In moments, the smoke is 15,000 feet high and curdling into bleached cumulus clouds.

"That's the instability!" Ruthford says, as the smoke column expands skyward. The air over Lake Chelan clears, and in the distance, three more smoke towers punch into the atmosphere. Ruthford, pleased with the accuracy of her forecast, turns back to the truck. She's inside and driving away before a column from a new fire outside the nearby town of Twisp begins to rise.

THE NEW FIRE OUTSIDE TWISP HAS TURNED DEADLY. "HOW MANY CAN WE AFFORD TO SEND?" SOMEONE ASKS.

• • •

THE SMOKE will eventually blow all the way to Chicago, but it's just starting to bend over the fire camp by the time Ruthford returns. The winds are still strong, howling up the Columbia River. They roll great clouds of dust between the yurts. The afternoon light is tinted orange. Solemn-looking firefighters stand in small groups, talking quietly. The new fire outside Twisp has turned deadly. "How many can we afford to send?" someone asks.

Eventually, everyone is called into a large central yurt. Shortly after the new blaze began, flames spread toward town. Helicopters, firefighters, and engines were pulled off the Chelan complex and neighboring fires, and sent 50 miles away to the new blaze. One was Engine 642 from the Forest Service's Methow Valley Ranger District.

When the winds reached the ridge outside Chelan, they also blew over the new fire, as Ruthford predicted. An hour later, firefighters found Engine 642's crew about 40 feet below Woods Canyon Road. Inside were the burned bodies of 20-year-old Tom Zbyszewski, 26-year-old Andrew Zajac, and 31-year-old Richard Wheeler. Outside, 25-year-old Daniel Lyon lay in white ash, critically burned.

News of the deaths hit Ruthford and the Chelan complex's fire camp like a gut punch. The firefighters disperse from the meeting. Some head to dinner, because what else is there to do? Others linger in the avenue and cry. Some go to the docks to be alone. Ruthford heads for her desk.

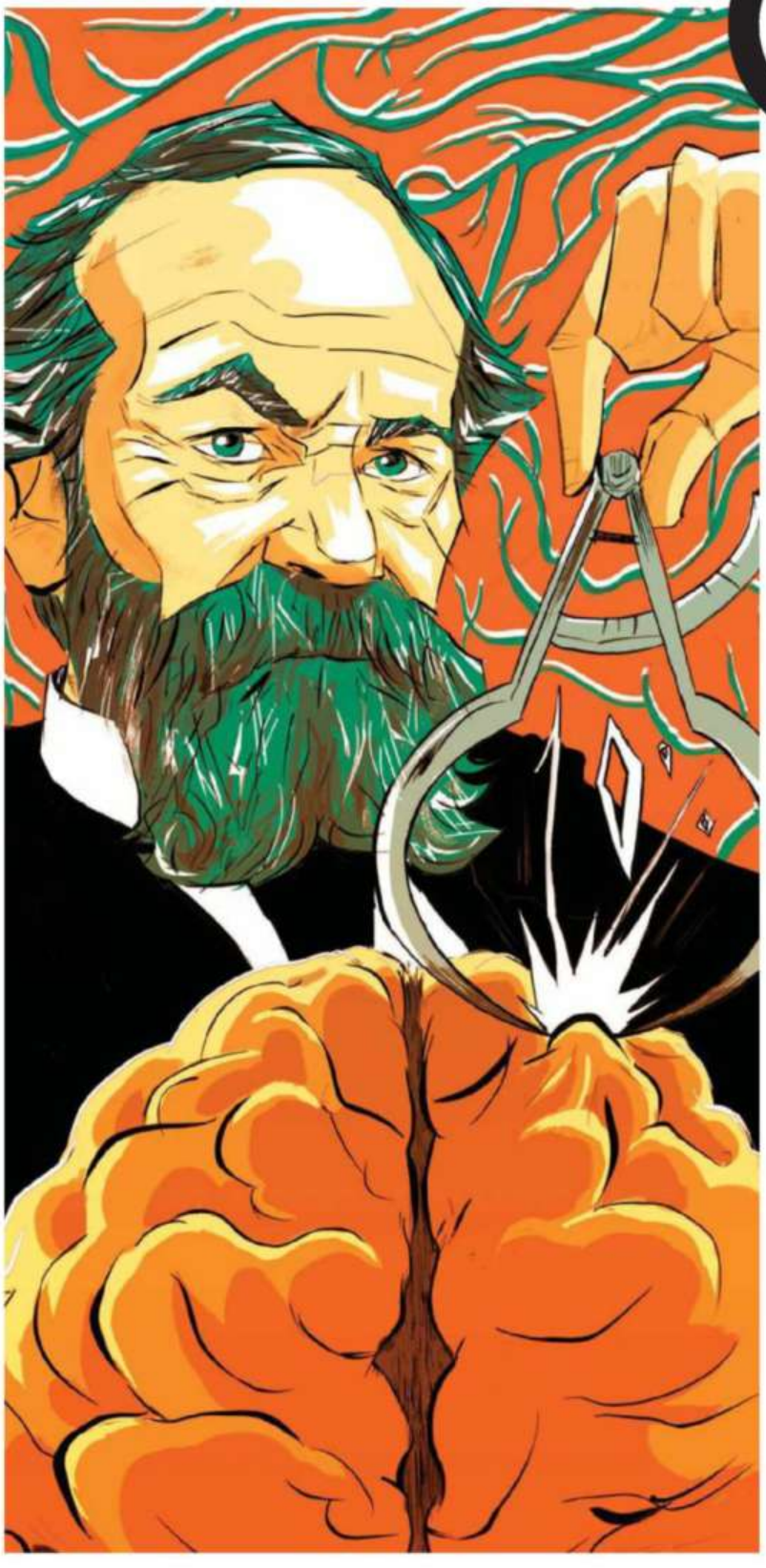
Her face is pulled tight like she's nauseous. Todd Gregory, a fire-behavior analyst, comes over, gently tapping the forecasts piled before her. "It's not your fault. You don't make the weather," Gregory says, "you just predict it."

Gregory leaves, and Ruthford remains in the yurt alone. For a long time, she just sits. Then she sighs and opens her laptop. She has a morning forecast to produce, and tomorrow's weather looks worse.

BRAIN MYTHS BUSTED

In the Hollywood action-film *Lucy*, actor Morgan Freeman—playing a world-renowned neurologist—speaks to a packed auditorium. "It's estimated most human beings only use 10 percent of their brains' capacity," he says. "Imagine if we could access 100 percent." You may have heard that claim before. Unfortunately, it's just not true. And after watching *Lucy*, Ramina Adam and Jason Chan, two neuroscience graduate students at Western University in Ontario, decided to set the record straight. "We realized we had to do something about all this misinformation," Adam says. They set out to collect common misperceptions about how the brain works, and we lent a hand in debunking them.

By **Megan Scudellari** • Illustrations by **Ryan Inzana**



1 We use only a fraction of our brains.

In 1907, famed psychologist William James claimed, "We are making use of only a small part of our possible mental and physical resources." A journalist later misquoted him as saying the average person develops only 10 percent of his mental capacity. Scans, however, show that we use every part of our brain, though not all regions are active at once. (Sorry, Morgan.) That's why damage to any area of the brain—such as the aftermath of a stroke—usually results in mental and behavioral effects.

+

STAY SHARP!

While crossword puzzles and classical music aren't going to make you smarter, here are three proven strategies to keep your brain at peak performance for your entire life.

2

Playing classical music to infants makes them smarter.

The state of Georgia began distributing classical-music CDs to the families of newborns in 1998. Each CD included a message from the governor: "I hope both you and your baby enjoy it—and that your little one will get off to a smart start." While the sentiment is appealing, the so-called Mozart Effect is dubious. The idea sprang from a 1993 study at the University of California at Irvine, which showed that 36 college students performed better on an IQ test after listening to Mozart than after relaxation exercises or silence. No one has been able to replicate those results. In fact, a 1999 Harvard University review of 16 similar studies concluded the Mozart Effect isn't real.

3

Adults can't grow new brain cells.

Adult rats, rabbits, and even birds can grow new neurons, but for 130 years, scientists failed to identify new brain-cell growth in adult humans. That all changed in 1998, when a Swedish team showed that new brain cells form in the hippocampus, a structure involved in storing memories. Then, in 2014, a team at the Karolinska Institute in Sweden measured traces of carbon-14 in DNA as a way to date the age of cells, and confirmed that the striatum, a region involved in motor control and cognition, also produces new neurons throughout life. While our brains aren't exactly an orgy of wildly replicating cells, they do constantly regenerate.

4

Male brains are biologically better suited for math and science, female brains for empathy.

There are small anatomical differences between male and female brains, this much is certain. The hippocampus, involved in memory, is usually larger in women, while the amygdala, involved in emotion, is larger in men. (The opposite of what you'd expect from this myth.) But evidence suggests gender disparities are due to cultural expectations, not biology. For example, in 1999, social psychologists at the University of Waterloo in Ontario gave women and men a difficult math test. Women—even those with strong math backgrounds—scored lower than men, unless told the test had revealed no gender differences in the past. Then the women performed equally well as the men.

5

Being in a coma is like being asleep: You wake up intact and well rested.

In the movies, comas look harmless: A well-groomed patient lays in bed for a few months and wakes fully articulate, seemingly unscathed by his or her ordeal. In real life, those emerging from comas often suffer disabilities and need rehabilitation. Brain scans point to why. Scientists at the French National Center for Scientific Research, in 2012, found that high-traffic brain regions—normally bright hubs of activity, even during sleep—are eerily dark in coma patients (while other areas inexplicably light up). Most comas also don't last more than two to four weeks. So don't believe everything (or anything) you see on *Grey's Anatomy.*

GET THE BLOOD FLOWING

In a 2014 study at the University of British Columbia in Canada, women who walked briskly for an hour twice weekly for six months—but not those who strength-trained or did no exercise—increased brain volume in the areas that control thinking and memory.

EAT YOUR GREENS

A team of researchers with the federally funded Nurses' Health Study tracked 13,388 women over decades and discovered the more leafy vegetables they ate, the better they performed on learning and memory tests. That might be due in part to folic acid in veggies: A long-term study of 60 Roman Catholic nuns in Minnesota identified folic acid as a key factor in delaying the onset of dementia.

TALK TO PEOPLE

In 2004, scientists at Johns Hopkins University found that more social interaction was associated with less cognitive decline for people aged 50 and above. Plus, one of the major risk factors for death in the elderly is social isolation—loneliness really can kill you.

6

Doing crossword puzzles improves memory.

If you've ever despaired at the Sunday crossword, here's good news: Neuroscientists have found that doing crossword puzzles makes you very good at—drumroll, please—doing crossword puzzles. A 2011 study, led by researchers at the Albert Einstein College of Medicine, found that solving crossword puzzles initially delayed the onset of memory decline in individuals between the ages of 75 and 85, but sped the decline (for reasons unknown) once a person showed signs of dementia. Today, most neuroscientists agree there is no harm in the activity. But don't expect it to make you any better at finding your keys come Monday morning.

7

Students learn best when teaching styles match their learning styles.

Ever asserted that you need lessons delivered visually or verbally? We hate to break it to you, but there's just no support for that. In 2006, psychologists at the University of California at Santa Barbara found that students didn't perform any better on a test when given instructions in their preferred style. And a 2009 review paper found no studies upholding the claim—popular among both educators and students—that teaching and learning styles should match. That said, there are broad principles under which everyone seems to learn better, such as through repetition, testing, and by spacing out learning sessions.

8

Drinking alcohol kills brain cells.

That woozy feeling you get after three or four glasses of wine isn't from brain cells expiring. When scientists at the Bartholin Institute in Denmark compared the brains of deceased alcoholics and nonalcoholics, they found the total number of neurons to be the same. Alcohol, like other substances, can kill brain cells at high doses (especially the sensitive brain cells of developing fetuses), but moderate alcohol use does not. It does interfere with how neurons communicate, affecting one's ability to perform tasks like walking, speaking, and making decisions. But you already knew that.

9

We know what you're thinking: ESP is a scientific certainty.

Extrasensory perception (ESP), the so-called sixth sense, can be traced back to an experiment in the 1930s. Joseph Banks Rhine, a botanist at Duke University, claimed that individuals who were shown the blank face of a card could correctly guess a shape printed on the back (supposedly by reading the mind of the person administering the test). Although no other type of test has produced evidence for ESP, the myth lives on—thanks in part to the CIA, which employed psychic spies during the Cold War. The spymasters shut down their psychic network in 1995, when they finally concluded ESP isn't a weapon—or even a thing.

+

PLOT TWISTS

"Neuromyths have gotten folded into popular culture," says Nicholas Spitzer, co-director of the Kavli Institute for Brain and Mind at the University of California at San Diego. "It's been an uphill battle to dispel them." Here are three culprits from TV and the movies. **NICOLE LOU**

Myth: Alcohol kills brain cells.

Before taking his remedial high school science exam, Homer says in *The Simpsons* (1993), "All right, brain. You don't like me and I don't like you, but let's just do this and I can get back to killing you with beer."

Myth: ESP is a scientific certainty.

The premise of Steven Spielberg's *Minority Report* (2002) rests on the ability of a psychic police force to stop murders before they happen (and gives rise to a slew of ESP-centric crime shows, such as *Medium*).

Myth: Being in a coma is like being asleep.

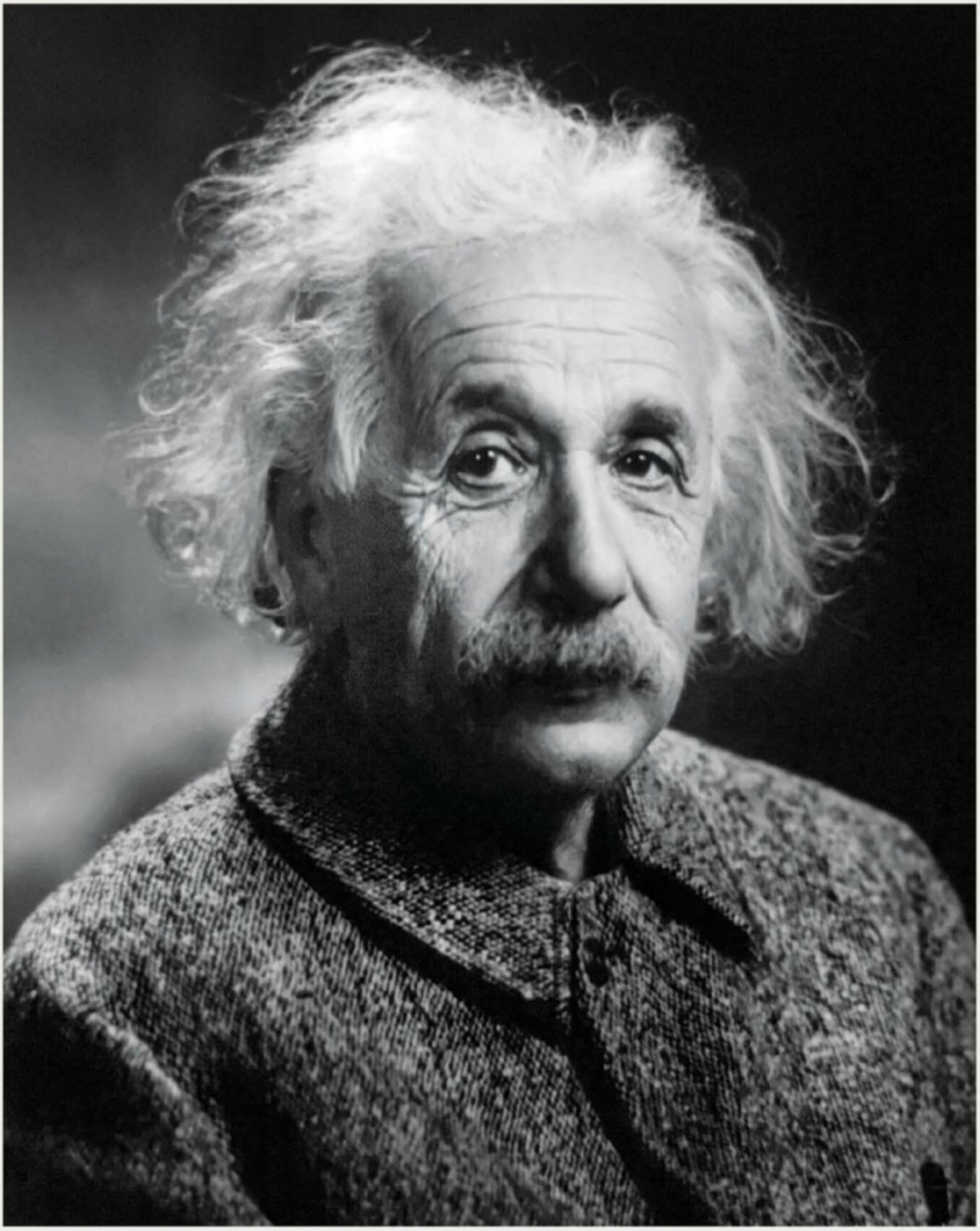
A single mosquito bite awakens Beatrix Kiddo, the Bride in Quentin Tarantino's *Kill Bill: Vol. 1* (2003). After spending four years in a coma, she is able to get out of bed and immediately begin a killing spree.

LEFT TO RIGHT: COURTESY FOX; EVERETT COLLECTION (2)

10

Some people are left-brained (logical) and some are right-brained (creative).

In the 1960s, Roger Sperry, a neuropsychologist at the California Institute of Technology, cut fibers connecting the brain's two hemispheres in a handful of epilepsy patients to reduce or eliminate their seizures. He then ran an experiment, flashing images—of letters, lights, and other stimuli—into either the left or right eye of the patients. Sperry found that the brain's left hemisphere better processed verbal information and the right hemisphere, visual and spatial. Over decades, those findings became misinterpreted as dominance, particularly in self-help books. There is no evidence to support personality types based on dominant hemispheres, but there's plenty of evidence to refute it: In 2012, for example, psychologists at the University of British Columbia found that creative thinking activates a widespread neural network without favoring either side of the brain.



Albert Einstein, Landscape Architect

The physicist's most famous theory just turned 100. And today, general relativity still yields astonishing discoveries about the universe.

BY
Corey S. Powell

In 1913, Albert Einstein had stalled in his efforts to construct his general theory of relativity. He pleaded with his friend Marcel Grossmann for a mathematical boost: "Grossmann, you've got to help me, otherwise I'll go mad!" Four years later, as Einstein was finishing a paper on the cosmic implications of his (finally) completed theory, the malady had migrated to other parts of the body. He had a stomach ulcer; he suffered from liver disease. Worn out by his mental exertions, Einstein thought he was dying. He wrote to fellow physicist Arnold Sommerfeld: "In the last month I had one of the most stimulating, exhausting times of my life, indeed also one of the most successful."

That sensation eluded most of his colleagues back then, and it still does. They study Einstein's greatest insight without fully grasping how he achieved it, or what it meant to him; they typically don't "feel relativity in their bones," in the words of Columbia University theoretical physicist Brian Greene. The lack of understanding comes from a sticky misconception of what general relativity is, even among those who spend their careers making use of it. It is broadly described as a theory of gravity, but it is not just a theory. It is written out as a series of equations describing how objects move, but it is not just equations.

General relativity is best thought of as a landscape, both literally and figuratively. It is an expanse of concepts that describes all the possible configurations of space and time, and all the ways they change in the presence of matter. It is a system in which every part of reality is connected. Einstein's first forays into that landscape were what so exhilarated and drained him. Whenever other researchers manage to follow his lead, they discover whole new regions. That is why, a century after it was first published, general relativity is yielding its most astonishing discoveries yet.

There is no better way to take in the idea of relativity-as-landscape than by looking at the biggest landscape of all: the universe. Einstein realized that space is not a fixed background (a kind of invisible ruler that you can measure motion against), but rather a flexible, dynamic thing that bends and distorts in response to mass. That bending is what we experience as a gravitational pull: It holds your feet to the ground and Earth in its orbit. Lee Smolin—a theorist at the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, and one of Einstein's most vocal disciples—praises general relativity's ability to provide a single, unified description of all space, as determined by all mass. "It's the first theory that can be applied to the universe as a whole in a closed system," he says.

You've surely heard scientists say that the universe is expanding, but what does that really mean? In 1929, Edwin Hubble observed that galaxies appear to be moving away from ours in all directions. It is tempting to picture those galaxies flying through space, driven apart by a tremendous initial explosion. In fact, in the 1930s, British astronomer E.A. Milne attempted to describe Hubble's discovery in just those terms. His analysis was a dismal failure. The only way to make sense of the astronomical observations, Einstein showed, is to think of space as a dynamic thing. Galaxies are not flying through space; space itself is expanding between them.

That is a profoundly weird notion, but once you make peace with it, all kinds of other ideas fall into place. First and foremost, there is the Big Bang, which was not an explosion *in* space but an explosion *of* space. All of space was crammed into a single dot at the moment of the Big Bang, and all of space expanded out from there in the 13.7 billion years since. Because space is expanding in all directions, any spot can be considered the center of the universe. You, right there, right now, are at the center of the universe. (How's that for an ego boost?) Relativity is what allowed cosmologists to model the origin of the elements, the formation of galaxies, the direct evolutionary path from the Big

LIBRARY OF CONGRESS—OREN JACK TURNER/GETTY IMAGES

In 1947, at age 67, Einstein persevered in developing a single unified theory that would combine electromagnetism and gravity—a quest that still eludes physicists today.

Bang to modern Earth.

And still they are exploring new corners of relativity's landscape. Because space is dynamic, it can deform in all kinds of complicated ways. The pull of gravity works to compress it; that compression is what you experience as your weight. Einstein's equations also allow for antigravity, an energy that pushes space apart. For decades, that possibility was regarded as little more than a theoretical curiosity. Then in 1998, two teams of astronomers observed that the expansion of the universe is accelerating. This makes sense only in the context of relativity. The antigravity element driving the acceleration is now called "dark energy," and it is so well-accepted that the 2011 Nobel Prize in physics was awarded for its discovery.

The true nature of dark energy, however, remains an enigma. To figure it out, an international team of astronomers launched the Dark Energy Survey, currently underway at the Cerro Tololo Inter-American Observatory in Chile. Over the course of five years, they will be photographing 300 million galaxies and recording their distribution. Gravity tends to make galaxies clump together over time, whereas dark energy tends to scatter them. The pattern captured by the survey will begin to reveal whether dark energy works the same in all locations and whether its intensity has changed over the course of cosmic history. Dark energy outweighs all the visible galaxies by about 15-to-1, and so its influence might determine the fate of the universe.

Just as space can expand, so it can ripple when disturbed by the gravity of a moving object, like the surface of a pond stirred by a skipping stone. This is another wilderness of relativity that scientists are only now exploring. As gravitational waves wiggle past Earth at the speed of light, they subtly squish and stretch everything they encounter—including you. The effect is exceedingly subtle. To discern these waves, researchers are upgrading a pair of 2.5-mile-long detectors—one in Washington state, one in Louisiana—called the Laser Interferometer Gravitational-Wave Observatory (LIGO), along with a complementary experiment called Virgo, located in Italy. By the end of the decade, they hope to observe gravitational signals emanating from spectacular but otherwise invisible cosmic events such as colliding black holes.

Ah, yes, black holes—perhaps the most famous of all the bizarre features that have emerged from the landscape of Einstein's equations. Black holes are places where space curves in on itself; nowhere is relativity's topography more tortured and intriguing. At the event horizon—the boundary of the hole—time comes to a halt and the atom-scale phenomena described by quantum mechanics are stretched out to the size of cities...or so it seems. General relativity also states that all parts of the universe should be continuous, meaning there should be no physical interruption between the inside and outside of a black hole. That apparent contradiction is inspiring a storm of new theories that go beyond scientists' current understanding of the laws of physics.

Even in the twisted case of black holes, concepts that seem to reside in the impossibly remote fringes of the relativity landscape might be approachable to hard observation. A globe-spanning instrument called the Event Horizon Telescope, which consists of nine radio observatories scattered around the world, is

CONTINUED ON PAGE 71 →

BORN March 14, 1879, Ulm, Germany

AGE 5

1880 MOVES TO MUNICH

1895 Throughout his schooling, he aces math and physics but does less well in other subjects. Einstein's father, Herman, writes to an instructor:

"With Albert, I got used a long time ago to finding not-so-good grades along with very good ones."

1896 HEADS TO COLLEGE IN ZURICH

1902 BEGINS WORK AT THE ZURICH PATENT OFFICE

1905 Einstein's "miracle year," when he publishes four major works—including his special theory of relativity and a paper on the nature of light, which would earn him the Nobel Prize.

June 1905 He explains to a friend how he's so productive, despite holding a full-time job as a patent clerk:

"Keep in mind that besides eight hours of work, each day also has eight hours for fooling around, and then there's also Sunday."

December 1921 Einstein wins the Nobel Prize in physics for his 1905 paper on the photon nature of light. In his Nobel speech, however, he chooses to discusses his current obsession instead: relativity.

March 1920 Einstein continues to develop GR, if in fits and starts:

"I am constantly brooding about extending the theory of relativity, but always come up against a wall."

1922 Following his Nobel win, Einstein grapples with fame. To his friend Heinrich Zangger:

"Worshipped today, scorned or even crucified tomorrow, that is the fate of people whom—God knows why—the bored public has taken possession of."

December 1928 With a colleague, Einstein files a patent for a refrigeration system that uses liquid metals as coolants. His refrigeration pump design was used in early nuclear reactors but never found broad commercial operation.

CORBIS

Einstein's Work and Life, In His Own Words

Albert Einstein formulated general relativity (GR) over the course of a decade, and then ruminated on its implications for the rest of his life. Though GR kept him busy, the physicist found time to ponder a host of other ideas—and do a lot of living. The Einstein Papers Project, based at Caltech, shows as much. The team is curating, digitizing, and translating Einstein's notebooks and letters to help scholars understand what occupied his mind. The 14 volumes published so far—through 1925, when Einstein was 46—reveal a hardworking scientist who wasn't afraid to unleash some sass. **SHANNON PALUS**

Nerd Box: Excerpts from Einstein's letters are colored by topic.

LIFE

GENERAL RELATIVITY

OTHER WORK

April 1906 He fears he's peaked. To a student and colleague:

"Soon I will reach the age of stagnation and sterility when one laments the revolutionary spirit of the young."

September 1907 An editor requests a review article on special relativity. It spurs Einstein to think about how his 1905 theory might be applied more broadly. Special relativity doesn't account for accelerations, whereas general applies just about everywhere.

January 1908 He struggles with general relativity (GR), and worries that other scientists' expectations are too high. To a fellow physicist:

"Thanks to my having hit upon the fortunate idea of introducing the [special] relativity principle into physics, you (and others) enormously overestimate my scientific abilities, to the point where this makes me somewhat uncomfortable."

1908–13 TEACHES AT FOUR GERMAN AND SWISS SCHOOLS

March 1909 Though Einstein pondered the new century's hottest topic—splitting atoms—he wrote to physicist Hendrick Lorentz that his grasp of it was superficial at best:

"I am sending you a short paper on radiation theory, which is the trifling result of years of reflection. I have not been able to work my way through to a real understanding of the matter."

May 1909 While at the patent office, Einstein showed that light behaves as if it's made of photons, or "quanta." But light can also act as a wave—and that duality has become foundational to quantum mechanics. He acknowledges his quanta picture is incomplete:

"I am not at all of the opinion that light has to be thought of as being composed of mutually independent quanta."

November 1911 Einstein writes Marie Curie a fan letter:

"I am impelled to tell you how much I have come to admire your intellect, your drive, and your honesty."

1913 MOVES TO BERLIN

AGE 35

November 1915 Einstein publishes GR, a mathematical framework that explains the underlying mechanism of gravity: Masses produce accelerations by warping space-time.

September 1919 A team observing a solar eclipse confirms that gravity bends light rays in the way GR predicts. He writes to his mother:

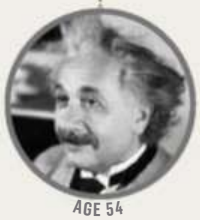
"Today some happy news. H.A. Lorentz telegraphed me that the English expeditions have really verified the deflection of light by the sun."

October 1936 Einstein publishes a patent for a camera that adjusts to different light intensities, the only one of his 21 patents in seven countries that was based on his Nobel Prize-winning physics.

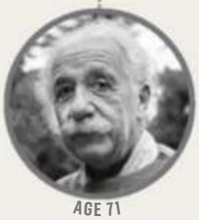
1933 MOVES TO THE UNITED STATES; LIVES IN NEW JERSEY

1937 Einstein extends GR further in a paper on gravitational waves, which are still being hunted by physicists today. He's a self-assured scientist: He publishes the work in a small journal after spurning the peer-review process at a better-known journal, the *Physical Review*. To an editor at the *Review*:

"I see no reason to address the erroneous comments of your anonymous expert."



AGE 54



AGE 71

Dies
April 18, 1955
Princeton, N.J.

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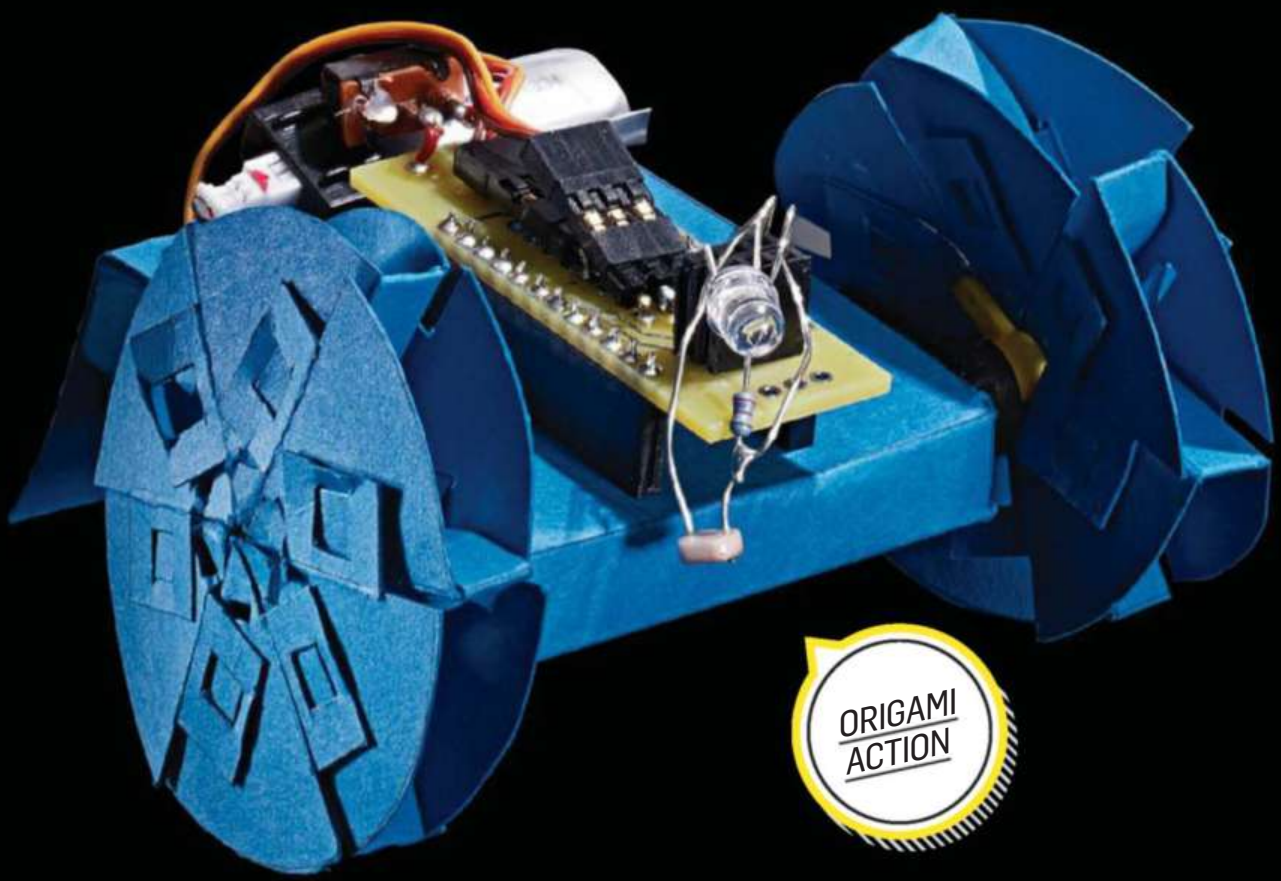


Fold a Paper Robot

Origami, the ancient art of paper folding, also shows up in modern science and engineering. By turning a two-dimensional sheet into a 3-D product, as origami artists do, engineers can make more-versatile versions of devices like space mirrors and heart stents. The same techniques can also be used to create inexpensive robots.

To get started, simply print out a template, cut, and fold. Once you add some basic electronics, an Arduino brain will command the robot to roll over the floor, sticking to dark surfaces, based on the amount of reflected light it detects. If the robot's body tears, it's no big deal. Cardstock costs only about 10 to 30 cents per piece—just print another.

Ankur Mehta, who was an MIT postdoctoral fellow when he designed this machine, says his goal is to get robots into anyone's hands for cheap. "People who are not engineers should be just as comfortable with creating and using robots as they are interacting with cellphones and smart devices," he says. **LIZ KRUESI**

Visit *popsci.com/paperbot* for the folding guide, photos, sample code, and more.

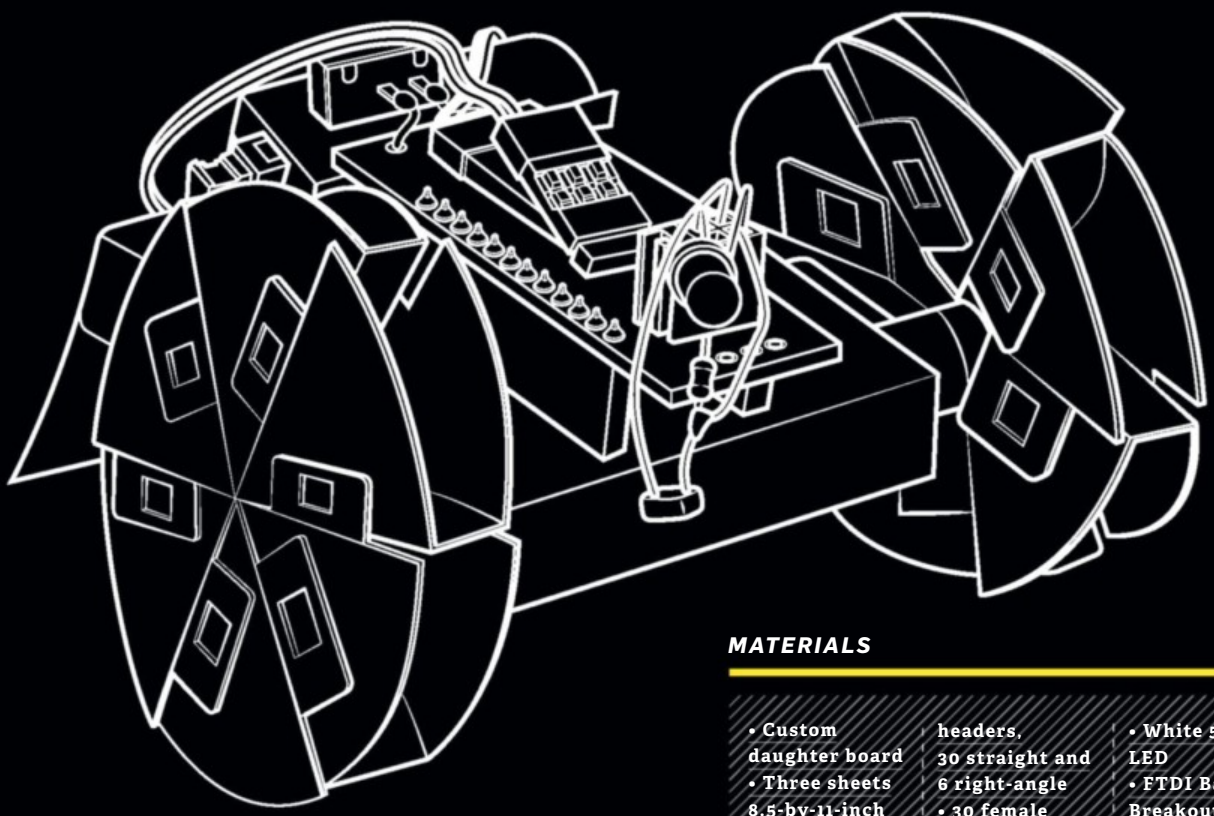
continued on page 60

PHOTOGRAPH BY *Bryan Edwards*

Build It

continued from page 59

WARNING: Lithium-polymer batteries are a fire hazard. Read the warnings on your battery before plugging it into your *paper* project.



TOOLS

Printer | X-Acto knife | Straight edge | Soldering iron

MATERIALS

- Custom daughter board
- Three sheets 8.5-by-11-inch cardstock
- Two continuous-rotation servos
- Arduino Pro Mini 3.3V/8MHz
- Male breakaway headers, 30 straight and 6 right-angle
- 30 female headers
- Switch
- Connector for battery
- 1.8-kilohm resistor
- Mini light sensor
- White 5 mm LED
- FTDI Basic Breakout 3.3-volt
- Li-poly 3.7-volt, 130mAh 1S 25-40C battery
- Li-poly battery charger

INSTRUCTIONS

1 Order a custom daughter board (based off the circuit diagram at *popsci.com/paperbot*) from a printed circuit-board service such as OSH Park.

2 Print the body and wheel patterns from the online folding guide onto cardstock and carefully cut along the red lines, using the straight edge to guide the knife. (Cut the outline first; wait to cut the details until after you've made the major folds.) Make mountain-folds along blue lines and valley-folds along green ones.

3 Assemble the wheels. Slide both arms of a plastic servo double-arm into two opposite cut-outs at the center of each wheel.

4 On the Arduino, solder six male single pins into the programming header at board top, and solder 12 single male headers along each side on board bottom.

5 Solder three right-angle male headers into rows 9 and 6 on daughter-board bottom and six female headers into its ANLG holes (this is where the LED, light sensor, and resistor will fit). Solder the switch to board bottom. Solder battery-connector wires into the (+) and (-) holes on board top. Solder 12 single female headers along each side of the board top.

6 Place the Arduino in the second largest paper segment. Make sure the pins go through the holes. Slide tabs of the two smallest servo paper segments into slots on the Arduino paper segment. Place the rectangular parts of the servos into their segments so their shafts are sticking out through the paper cutouts.

7 Fold the rest of the paper structure around the Arduino and servos; close all tabs. Snap the double arms (attached to the wheels) onto the servos. Tightly attach the daughter board's female connectors to the Arduino's male pins (piercing through the top piece of cardstock) so the switch is toward the robot's tail. Connect the servo wires to rows 9 and 6.

8 Solder one end of the resistor to the light sensor. Connect resistor and light sensor to the frontmost three female headers. Connect the LED to two female headers.

9 Upload code to the Arduino using the FTDI Basic Breakout 3.3 volt.

10 Place the battery between the daughter board and the paper, and plug it in. Your paper robot is ready to rock—or rather, roll.

ILLUSTRATION BY CLINT FORD

SCULPTURES WITH A LIFE OF THEIR OWN

Twenty-five years ago, artist Theo Jansen built a new life-form. Made of PVC pipes and zip ties, his strandbeest (Dutch for "beach beast") walked along a beach under wind propulsion. Since then, Jansen has created many more beests and inspired a small army of imitators.

Some of his strandbeests, and other makers' so-called hackbeests, will begin their first-ever tour of U.S. museums this fall. They will be on view at their first stop, Salem's Peabody Essex Museum, through January. **REBECCA HARRINGTON**

BEEST Hamster Walker
MAKER I-Wei Huang, videogame toy and character developer
NUMBER OF PARTS About 125
HOW IT WORKS "A strandbeest looks more like a living thing than a bunch of pipes," says Huang. The observation led him to incorporate an actual animal into his machine. A hamster running inside a clear ball propels the plastic legs of this hackbeest forward.

"The perfect strand-beest is a specimen that lives on its own—so I don't have to think about it anymore."
—THEO JANSEN

BEEST Multiple Part Test No. 2
MAKER Maxwell Yakush, machinist
NUMBER OF PARTS More than 400
HOW IT WORKS To devise "the most elaborate executive desk toy ever," Yakush took inspiration from Jansen's work. "It's just tubes and string, but his contraptions are so fun to watch," he says. Yakush's aluminum creation uses gravity (or a spin of its windup wheel) to walk down hills.

BEEST Cajun Crawler
MAKER A mechanical engineering class at the University of Louisiana at Lafayette
NUMBER OF PARTS More than 200
HOW IT WORKS The students wanted to make a machine "that would be not only functional but also beautiful," says their professor, Terrence Chambers. They can ride their aluminum hackbeest like a Segway and control its speed with a squeeze of the handlebars.

Theo Jansen and one of his strandbeests, Animaris Umerus, walk along a beach in the Netherlands.

MAIN IMAGE: PHOTOGRAPH BY LOEK VAN DER KLIS/FLICKR; INSET IMAGES, LEFT TO RIGHT: COURTESY I-WEI HUANG; COURTESY MAXWELL YAKUSH; COURTESY AMELIA KANTROVITZ

I BUILT A 300 MPH PINGPONG CANNON

DIY-HISTORY COLUMNIST **WILLIAM GURSTELLE** GIVES ANCIENT WARFARE A MODERN SPIN

A world-class table-tennis player can smash the ball at almost 70 miles per hour. From my experience, it is darn difficult to return the ball at such speeds. Imagine a shot delivered more than four times faster—could even the best player hit it? To find out, I designed a pingpong cannon that shoots balls at nearly half the speed of sound.

The cannon's power comes from Boyle's Law, which (simplified) says that pressure is inversely related to volume. For example, if you put the air in a small reservoir under a lot of pressure and then release it into a larger one—such as the barrel of a gun—the pressure will drop. This causes the air's volume to expand instantly, shooting out any objects, like bullets, sharing that space.

Boyle's Law was also used to great advantage in one of the most historically important air guns of all time: the Corps of Discovery Air Rifle. It was wielded by the Austrian army at the turn of the 18th century but became best known as the weapon carried by Meriwether Lewis during the Lewis and Clark expedition of 1803-06. His rifle can still be seen today in the Virginia Military Institute Museum.

I built my own take on Lewis' weapon out of PVC piping. A small piece of pipe serves as the air reservoir. A water-sprinkler valve, which costs about $15 at the hardware store, controls the opening. I connected the valve's top cover to my air compressor's blowgun attachment. Then I pressurized the reservoir by adding air with a bicycle pump. When I pull the blowgun lever, it opens a port in the sprinkler valve, allowing high-pressure reservoir air to move into the longer PVC pipe that serves as the barrel. As the gas expands, it ejects a pre-loaded pingpong ball.

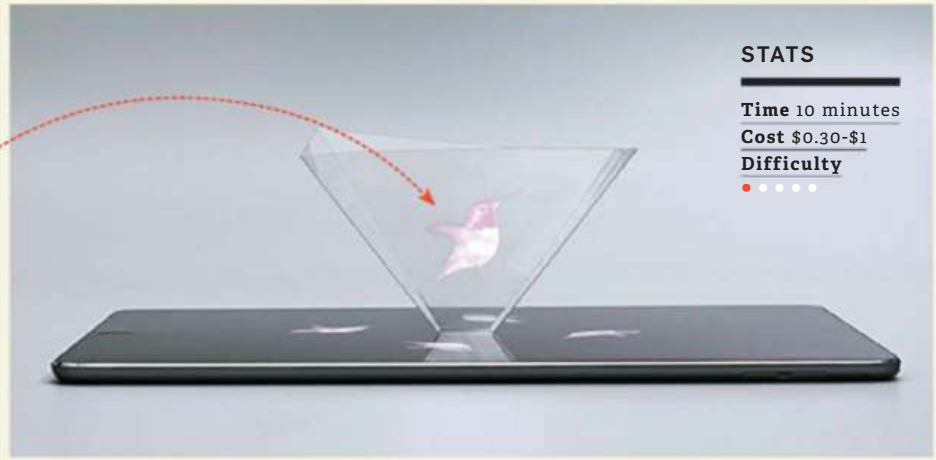
Measuring the speed with a ballistic chronograph, I recorded velocities greater than 300 miles per hour. So could a great table-tennis player actually return a serve at this speed? I recruited a volunteer and pressurized the cannon—visit *popsci.com/pingpongcannon* to see what happened.

WARNING: Don't stand in front of a pingpong cannon—for obvious reasons.

69.9 Speed, in miles per hour, of the fastest recorded table-tennis smash, achieved by New Zealand's Lark Brandt at the 2003 World Fastest Smash Competition

PHOTOGRAPH BY *Ackerman + Gruber*

Smartphone Hologram



STATS

Time 10 minutes
Cost $0.30-$1
Difficulty

Holograms aren't just for droids and dead rappers. You can make your own with a piece of transparency paper and a four-sided hologram video. Properly folded, the transparency will combine the images on a phone or tablet screen to create "a reflection that gives you the illusion of an object hovering in space," says Alex Cronin, a physicist at the University of Arizona. **LEVI SHARPE**

For the template, a hologram video, and more, visit popsci.com/holophone.

PHOTOGRAPH BY BRYAN EDWARDS

MORE OPTICS HACKS

A smartphone can perform other optical tricks. Harvest a focus lens from a laser pointer, and attach it to the phone's camera with some wire. The lens will magnify images to make a DIY microscope. Or stick a few pieces of clear tape over the flash, and color them with blue and purple Sharpie markers. This filter blocks out most visible light and leaves only the ultraviolet spectrum, creating a blacklight camera.

TOOLS AND MATERIALS

- Sheet of transparency paper
- Pencil, pen, or marker
- Ruler
- Compass
- Scissors
- Smartphone or tablet

STEPS

1. Copy the online template onto the transparency, with a radius of 4 inches or more.

2. Cut along the solid black lines, and crease along the red lines.

3. Tape the two opposite sides together to make a prism.

4. Open a four-sided hologram video on your smartphone or tablet.

5. Place the small opening of the prism in the video's center. Look through the side.

500 | Maximum amount, in dollars, teams may spend on their cars for the 24 Hours of LeMons endurance race—safety tech excluded

LEMON RACER

PHOTOGRAPH BY MURILEE MARTIN; INSET JC IMAGES

In 2011, computer security specialist Erica Muxlow brought in her Ducati for service—but the repair shop overfilled the oil and routed the brake cable incorrectly. "I swore from then on that the only person who was going to touch my bike was me," she says. After getting her hands dirty on her motorcycle, Muxlow decided to hack her Mini Cooper. Teaching herself, she created a "mean little high-performance street car." Then she decided she wanted to build racecars.

At first, no racing teams near her Bay Area home would admit her. Several were openly skeptical that a woman had the skills to compete. She finally got her break when a work friend joined a team for the 24 Hours of LeMons, a national series of endurance races that involves cars hacked together on a budget. She hung around, proving her dedication and mechanical know-how with tasks like welding in a space so cramped, only she could fit into it.

Muxlow in Sesame State, her team's hacked 1986 BMW 325es, in Buttonwillow, CA, this June. The car lost third and fourth gears midrace—and still finished.

Today, Muxlow is a full-fledged mechanic and driver for the team, which is currently ranked first on the LeMons circuit. "The other guys don't treat me like 'the girl,'" she says. "They treat me like a teammate."

ANDREW ROSENBLUM

Go Ahead . . .

Ask Us Anything

Have a burning question? Email it to *askanything@popsci.com* or tweet it to @PopSci #AskAnything.

ANSWERS BY ***Daniel Engber***
ILLUSTRATIONS BY ***Jason Schneider***

Q: WHY DO STARS TWINKLE?

Short answer It's an optical illusion.

A:

Aristotle reasoned that stars twinkle because people need to stretch their vision to see them, and that vision wavers. Centuries later, scientists guessed that stars spin like diamonds, twinkling as they turn through different facets. It wasn't until the early 18th century that Isaac Newton determined Earth's atmosphere was to blame. The question was how.

Today, the generally accepted explanation is "stellar scintillation." Lorne Whitehead, a physicist at the University of British Columbia, describes it like this: A bright light, positioned far away, projects as a tiny point through the varying air densities of our atmosphere. Hundreds of these pockets act as lenses, refracting the light so that it moves like the light on the bottom of a swimming pool on a sunny day. The changing swells on the pool's surface correspond to the turbulent shifting of our atmosphere.

Though this theory is widely accepted, John Kuehne of the University of Texas believes the "lens-and-prism" model gets it wrong: "Everybody forgot the wave theory of light!" he says. We shouldn't think of starlight as a ray bending through the atmosphere, he says, but rather as a set of light waves that travel perfectly in sync. "The atmosphere puts wrinkles and crenelations into that wavefront," he says, knocking light out of phase and creating random patterns of interference. Thus, twinkle.

But Whitehead says it isn't necessary to complicate things in this way. "The ray model for light is a perfectly reasonable model for stellar scintillation," he says. "It gives the same exact answer."

The just-released John F. Kennedy presidential dollar figured to be among the most popular issues in the ongoing series of $1 coins honoring the nation's chief executives, now in the ninth year of its roughly 10-year run. JFK was one of America's most beloved presidents, and his shocking assassination ensured that his images would endure, as if frozen in time, in our nation's history.

Historic Coin Portrait The new coin design is the work of Don Everhart, a senior sculptor-engraver on the U.S. Mint's roster of staff artists. Depicting a contemplative JFK looking down and seemingly lost in thought, the image is similar to the official portrait hanging in the White House – also capturing Kennedy in a reflective moment, with his head bowed and eyes downcast. The portrait was painted in 1970, seven years after the assassination, and was closely monitored by Kennedy's widow, Jacqueline, who not only commissioned the artist, Aaron Shikler, but also gave him detailed instructions on how she wanted the president to be shown. The portrait differs greatly from the presidential images on other White House paintings, and Everhart has acknowledged that Shikler's work inspired the equally unique likeness of JFK on the coin.

A Woman's Touch It's a little-known fact, but Jacqueline Kennedy, one of America's favorite First Ladies, also played a role in the final design of the enormously popular Kennedy half dollar, which was first issued in 1964. She asked the coin's designer, Mint Chief Engraver Gilroy Roberts, to modify the details of her husband's hair - and the changes were, of course, made.

JFK, Purple Heart & Navy SEALs John F. Kennedy was a different kind of president – the youngest ever elected, recipient of a Purple Heart for his heroism, creator of the Navy SEALs, and the first (and so far only) Roman Catholic, to cite four important examples. In my opinion, such a president deserves a coin that likewise bears a historic design. I believe Don Everhart captured what Jackie and JFK would have liked, given the design of the presidential painting. I base this on a story my parents told me many years ago regarding an interaction they had with Jack and Jackie Kennedy at a 1959 dinner in Lake Charles, Louisiana. (See Bonus Gifts)

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Universal Coin & Bullion® is proud to announce that our President and America's Gold Expert®, Mike Fuljenz, was honored at the 2015 World's Fair of Money, receiving awards and recognition, including the prestigious "Book of the Year" award from the Numismatic Literary Guild for his newly released *Type Three Double Eagles 1877-1907 (Second Edition)*.

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try can do for you, ask what you can do for your country."

– John F. Kennedy

Inaugural Address
Friday, January 20, 1961

- *WWII decorated war hero-PT109 (Purple Heart, Navy and Marine Corps Medal)*
- *Pulitzer Prize Winner-Profiles in Courage*
- *House of Representatives / Senate*
- *Youngest U.S. President ever elected*
- *First Boy Scout to be U.S. President*
- *Founded the Navy SEALs*
- *Founded the Peace Corp*
- *Inspired America's goal of putting a man on the moon in the 60s (Kennedy Space Center is named after him)*
- *Only Democrat to be a NRA Life Member*

Where were you on November 22, 1963

Millions of Americans remember exactly where they were and what they were doing on November 22, 1963. Immediately following the tragic news about John F. Kennedy, Congress, the President, and the U.S. Mint worked with unprecedented (and uncharacteristic) speed and cooperation to replace the 90% silver Franklin Half Dollar with the 90% silver Kennedy Half Dollar in just months.

In early 1964, when the Kennedy Half Dollar was released to the public, people stood in long lines to buy them, quickly exhausting bank and store inventories. In 1965, President Lyndon Johnson signed the act that reduced the silver content of the Kennedy Half Dollar to 40%, thus ensuring that the 1964 silver Kennedy Half Dollar with 90% silver content would always be more desirable. Many parents and grandparents pulled slightly worn Kennedy Halves out of circulation. **The coins in this exclusive offer are far superior.**

Fifty years later, JFK's legacy continues to impact our nation and shape generations. To commemorate this historic year, Universal Coin & Bullion® has secured a limited quantity of original lustrous Brilliant Uncirculated*, first date of issue, 1964 Kennedy 90% silver half dollars. Each coin has been carefully hand-selected, and encased in a protective capsule to preserve their original luster, perfect for carrying in your pocket as a remembrance or securing in your collection.

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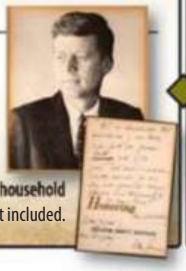

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ASK ANYTHING

NOVEMBER 2015

Q: How accurate are calorie counts?

Short answer Not very.

A:

America's century-old system for counting calories comes from chemist Wilbur Atwater. In 1887, he began to research the energy we get from eating by measuring the stored energy in foods and subtracting the amount left in people's bodily excretions.

Atwater's research has since been boiled down to the 4-9-4 rule: Each gram of protein, fat, and carbohydrate provides, respectively, 4, 9, and 4 calories of energy. The United States Department of Agriculture (USDA) has used these figures for decades, tweaking them only to account for different qualities—such as the digestibility—of specific foodstuffs.

But in the past few years, nutritionists have clamored for a reappraisal. For one thing, they say the present system ignores the difference between raw and cooked food. Harvard University researchers assert, based on mouse studies, that processed food is easier for the body to absorb, so it provides more calories. That goes for baked or blended food. Even a handful of chopped peanuts gives you more energy than whole ones.

In 2011, USDA researchers, with a grant from the nut industry, reported that the caloric value of pistachios had been overstated by 5 percent. In 2012, they found almonds were overstated by 32 percent, or 40 calories per serving. So you might not want to take nutrition labels at face value.

Q: WHY DOES A DROP OF WATER CONFUSE MY TOUCHSCREEN?

Short answer It conducts electricity, just like your finger.

A:

Modern touchscreens like the one on an iPhone work by measuring the change in charge and voltage across a grid of hair-thin electrodes, aka capacitance. "When you touch your finger to the screen, it sucks out some of the charge," says Geoff Wilson, a mobile-technology consultant and former touch technologist at Intel. That's because your body is made mostly of water, which is extremely conductive. The touchscreen locates your finger on the grid by measuring how much the charge drops between two intersecting electrodes, a process called "mutual capacitance."

The problem is that drops of sweat or rain can reduce the charge too by providing another conduit between the electrodes. Thankfully, over the past few years, touchscreen engineers have solved the water problem by drawing on a different mode of touch sensing called "self-capacitance." Instead of measuring the charge across pairs of electrodes, the touchscreen measures the increase in charge between an individual electrode on the screen and the ground you're standing on. Because water droplets aren't grounded, the phone's firmware is better able to ignore them.

However, this method alone won't work for most smartphones because it can't handle multitouch gestures such as pinches and zooms. The signal corresponds to rows or columns of the electrode grid, as opposed to individual points. With more than one touch, a phone might register ghost points in addition to real ones.

The solution? Combine the two methods in a single touchscreen. If the device checks for both signals, it can pick up multitouch gestures while controlling for sweat, rain, and other moisture. "It's the same electrodes and the same controller," Wilson says. "The only difference is the firmware, which has to be smart enough to combine the measurements." Some phones already come equipped with the combo, but that's rarely advertised. It's tough to make "mutual and self-capacitance" sound sexy in an ad.

Q: DOES "BRACING FOR IMPACT" REALLY PROTECT YOU IN A CRASH?

Short answer Yes, it could save your life.

A:

On January 8, 1989, a Boeing jetliner crashed during an emergency landing near East Midlands airport in England, killing one-third of the passengers on board. As doctors tended to survivors, they found that people who had adopted a "brace position" prior to the crash—heads bent forward, feet planted on the floor—were less likely to have sustained severe head trauma or concussions, no matter where they sat on the plane.

The Federal Aviation Administration has been using test dummies to study brace positions since 1967. While the recommended postures have changed a bit over the years, the underlying principle remains unchanged: It's best to lean forward in advance of a plane crash so your head is close to the seat in front of you. To press yourself toward the back of that seat, the theory goes, reduces the risk of deadly "secondary impact," wherein your head whips forward and slams into a hard surface.

Passengers in car accidents, who might have less time to act before a crash, reflexively brace for impact too. One study found that at least half the victims in head-on collisions press their heads and torsos back against their seats, locking their arms against the steering wheel or dashboard. While this position might increase the risk of breaking an arm or leg, it helps protect the head and chest from severe injuries.

Of course, the safest crash position depends on the nature of the accident and the design of the vehicle. Dipan Bose, a transport specialist with the World Bank, has studied emergency bracing positions using computer simulations. "This is all very directional," he says. "You have to know exactly which way the body will move." Easier said than done when it comes to car accidents, which are, by nature, unpredictable.

Albert Einstein

CONTINUED FROM PAGE 56

gathering information right now to create the first direct images of the supermassive black hole at our galaxy's center. The black hole itself won't look like anything (it's, um, black), but measurements of its size and surrounding structure could reveal the ways that mass distorts the structure of space. Any deviation from Einsteinian expectations would point the way to totally new physics concepts. The first meaningful images from the Event Horizon Telescope could come soon, perhaps within a decade.

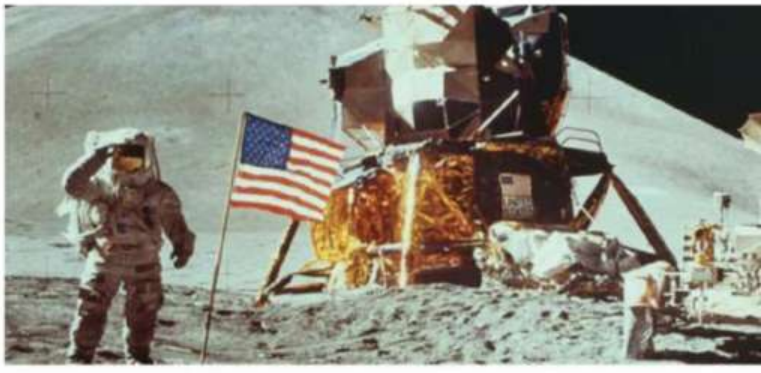
All of these ideas about the expanding universe, gravitational waves, and black holes took an excruciatingly long time to develop because they were hidden deep within the relativity landscape. Einstein himself was slow to accept the first two and never made peace with black holes, sniffing that the arguments for their existence were "not convincing," and assuming that natural processes prohibited them from forming. Many writers, including famed physicist George Gamow, have presented Einstein's resistance to these ideas as "blunders"—places where his great mind went off track. In reality, Einstein had opened up a landscape so vast that even he needed much more than a single lifetime to explore it.

Even as modern physicists press on far beyond where Einstein managed to go, their common assumption is that general relativity is not the final word. Relativity clashes with quantum mechanics—the set of rules describing the atomic-scale world—in its description of gravity and extreme objects like black holes. Forced to choose, most of today's theorists pick quantum mechanics as the more fundamental description of reality, regarding relativity as a large-scale phenomenon built from small-scale quantum effects. Physicists have done very well working from the bottom up (think of light interpreted as collections of photons, or matter as clusters of atoms), yet a century of experience suggests it is unwise to underestimate the power of Einstein's top-down perspective. As Lee Smolin puts it, quantum mechanics is a theory of "subsystems"—that is, it makes sense only in the context of its surroundings—in contrast to relativity's inherently cosmic scope.

Einstein's holistic approach is what makes general relativity unique in its potential for explanation and exploration. Surely there will be future physicists who venture even further into reality than he did. They may very well adopt many of the tools and techniques of quantum theory. But just as surely, those geniuses will have to act like Einstein—stepping back from equations to see the larger landscape—if they want to attain true enlightenment. They will have to feel relativity in their bones.

Company giving away advanced survival food to readers nationwide

Farmers vow to keep up with the rush to supply every reader who calls toll free and beats the deadline to claim up to four free 72-hour survival food kits.



25-year shelf life is ensured by packaging made of military-grade Mylar, the same material used to protect NASA astronauts.

In a crisis, your number one need is food. The question is, where will you get it if stores are closed for any length of time?

One company, Food4Patriots, is working to help ensure food will be available when it's needed. Recent advancements in the processing and packaging of their emergency foods have led to meals that are guaranteed to retain their fresh flavor for a minimum of 25 years. Other so-called survival foods have been reported to spoil or become infested with insects in just a few years.

And right now, in what is truly an unprecedented move, the company is giving away up to four 72-hour survival food kits to any reader of this magazine who wants to try their revolutionary product. The only requirement is that you call a special toll-free claim hotline before the program deadline.

Your family will enjoy meals much like what they're eating now.

"Survival food is more important today than ever before. Droughts, disasters, domestic violence, economic ills, monopolistic companies, even government controls could make obtaining sufficient food for your family impossible in the not-too-distant future," explained Frank Bates, a spokesman for the company. "And certainly, none of us ever wants to rely on a government agency to keep our families fed."

Experts say that everyone should have at least a 72-hour supply of non-perishable food on hand at all times. Unfortunately, too many people make the mistake of choosing products that were never intended to be survival food. They end up with expensive stockpiles that are too big and too bulky to move, should an emergency force them to leave their homes.

And if they were unlucky enough to stock up on MREs, they'll be depending on a product that can actually make them sick if they eat it for too long.

Food4Patriots survival foods are made of the finest ingredients, grown and packaged right here in the USA. They taste excellent. They provide the nutrition you need. And they were developed specifically for use in emergencies – although a lot of folks sometimes like them for a quick meal or snack.

Bates explained, "These are home-style meals that we package in airtight and resealable military-grade Mylar pouches that keep them fresh and delicious until they're needed. Your family will enjoy meals much like they're already eating every day."

Every 72-hour kit that's being given away contains four servings each of such familiar dishes as Liberty Bell Potato Cheddar Soup, Blue Ribbon Creamy Chicken Rice, Travelers Stew, and the always-loved Granny's Homestyle Potato Soup.

The company's usual price for the 72-hour kit is $27.00 plus shipping. But readers who act quickly can pay only the $9.95 shipping and handling fee through this program. There is a limit of four.

"We're trying to ensure no one who wants this free food misses out, but they have to hurry because we have a limited supply of the 72-hour kits we can give away," Bates warned. "Once word got out that folks could actually get free survival food, our phones have been ringing off the hook. We even had to add extra agents to keep up with the incredible demand."

There is still time to take advantage of this free food offer, but be aware the program will end no matter what at midnight, December 15, 2015."

HOW TO GET YOUR FREE 72-HOUR SURVIVAL FOOD KIT:

Food4Patriots is committed to giving a free 72-hour kit to everyone who calls their toll-free hotline. Just give the agent the approval code shown below. Provide your delivery instructions and agree to pay the $9.95 shipping and handling fee. That's all there is to it. (Limit: 4)

Approval Code: 72FREE
Toll-Free Hotline: 1-800-804-7508
Offer Cut-Off Date: 12/15/2015

Please note: Food4Patriots says they will continue to give away these 72-hour kits for as long as their supplies last.

Due to media exposure, their phone lines may be busy. Just keep calling and you will get through.

LETTERS

Dentist Recommends Vinegar

I have some useful advice that others may be interested in. When I got my Dentures several years ago, the Dentist told me use vinegar to get the plaque off them. So - about once a week I soak them in the wonder liquid and Presto - they sparkle.

I have since gotten implants - Since I am not fond of the hygienist scraping the posts for cleaning - I clean them with Vinegar before going for my check-up. On my last visit to her, she couldn't believe how clean they were and praised me for it!

I then asked the Dentist that put the implants in if the vinegar would harm the metal posts and he informed me it is OK to use it.

- D. L., *New Braunfels, Tx.*

Vinegar Heals Ear Ache in 2 days.

I have been plagued with an itchy ear for several months. It then developed into an earache. I was able to cure both the itch and earache in two days.

- J. D., *Jacksonville, Fl.*

NEWS & RESEARCH

Simple Vinegar used to reduce cervical cancer deaths by 31%

The latest study about vinegar, shows it will prevent an estimated 72,600 deaths from cervical cancer each year.

This according to a study released at the American Society of Clinical Oncology annual meeting in Chicago, IL.

The results were based over a 12 year period tracking 150,000 women in Mumbai, India, between the ages of 35-64 years.

The conclusion, a simple vinegar test significantly reduces cervical cancer deaths. Immediate plans are to implement this simple and successful screening test in developing countries.

The study had been planned for 16 years, but after the results were analyzed and found to be conclusive it was stopped at 12 years.

Vinegar has always been used for its versatility in home remedies, cooking and cleaning. And now scientific and medical findings are showing its a simple, low cost, non-invasive and safe for the patient.

Scarlett Johansson confesses her apple cider vinegar beauty secret

When celebrity beauty Scarlett Johansson needs to keep her skin looking beautiful and glowing one would think she would turn to high priced beauty creams.

Not so, according to an article in the February 2013 issue of Elle UK. She uses simple apple cider vinegar and its natural pH balancing properties to keep her skin looking amazing.

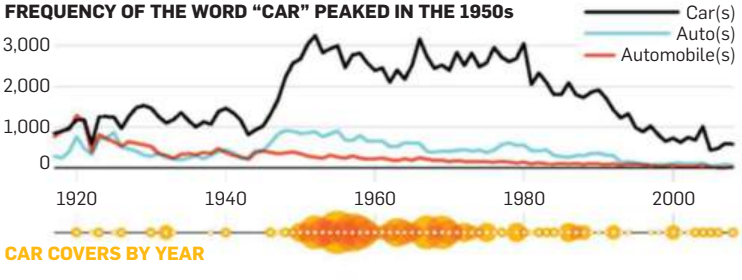
From the Archives

Efficient Autos Hit the Road

In May 1951, racecar driver Wilbur Shaw tested a batch of cars that—in contrast to the veritable barges trendy at the time—were billed as "little." They were cheap to purchase and drive. "You get what you pay for, and no more," was Shaw's assessment of the Henry J (in blue), which cost $1,360—about $12,500 in today's dollars. It lacked such amenities as a trunk door (penny-pinching owners would need to fold down the rear seats to retrieve their luggage). The pioneering compact car didn't sell, and Kaiser-Frazier manufactured it for only a few years. Though smaller cars did start finding favor in the 1970s, few of today's models are so light: At 2,300 pounds, the Henry J weighed about as much as a Fiat 500. But with U.S. fuel-efficiency requirements rising to 54.5 miles per gallon in 2025 (from 34.1 today), cars need to get lighter again, and quickly. Carbon fiber [page 38] and 3-D printing [page 35] might help automakers get there. **KATIE PEEK**

POPULAR SCIENCE'S ENDURING LOVE FOR CARS

The postwar years saw a jump in the magazine's auto coverage, a trend that lasted decades. From 1950 to 1980—when high-tech items such as computers start to appear—nearly every issue ran articles on cars, and many covers featured images of autos and their attendant tech.



Nerd box: Lines show how many times a year each term appeared in our articles and ads. Circles show the number of covers that featured vehicles.

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